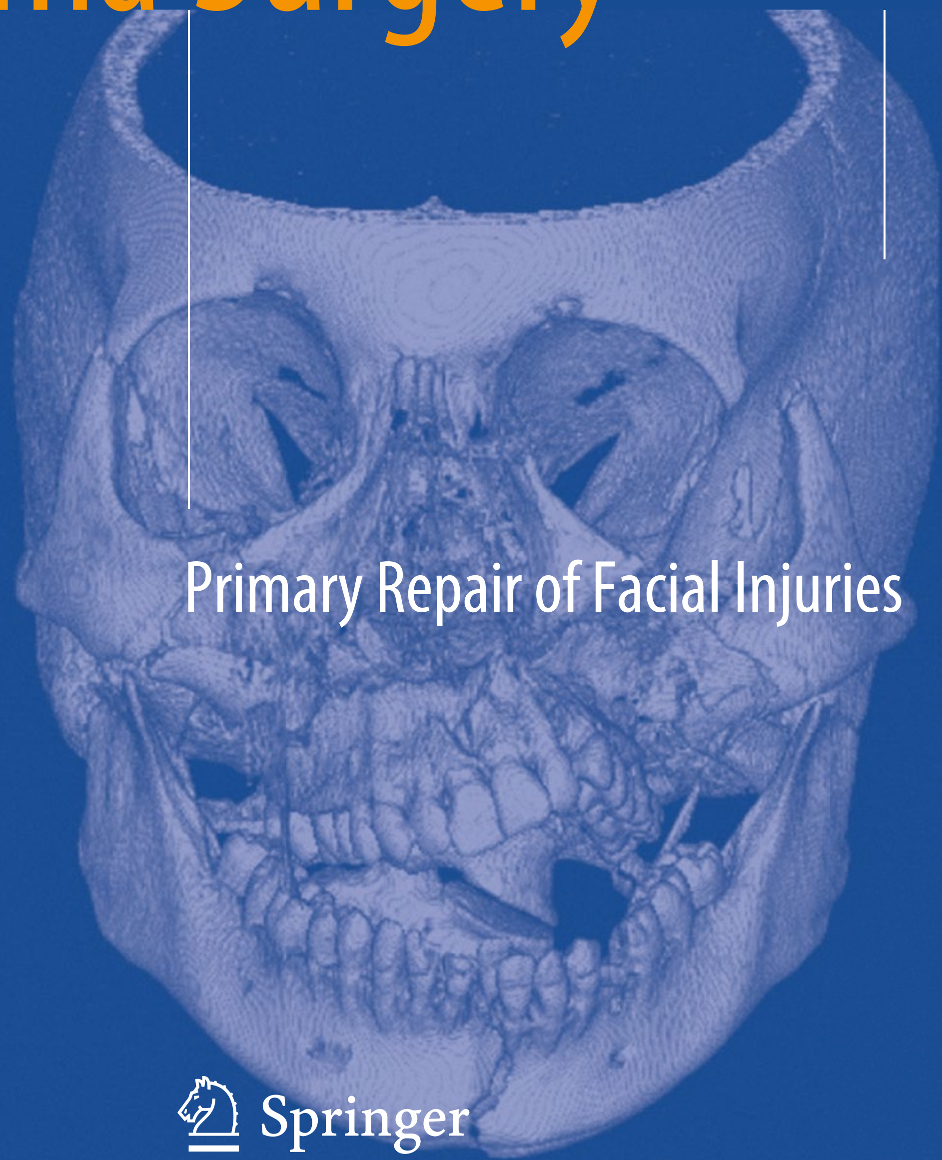
Michael Perry · Simon Holmes
Editors

Atlas of Operative Maxillofacial Trauma Surgery



Primary Repair of Facial Injuries

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Preface

Craniofacial trauma, in all its forms, is a challenging area of clinical practice, even in the twenty-first century. This is in part due to the highly visible effects it has on both the function and aesthetics of the face. Even "minor" injuries can result in significant disability and unsightly appearances if not precisely repaired. Although many facial injuries occur following relatively low-energy impacts (and can therefore be treated satisfactorily in many patients), the goal of *consistently returning our patients precisely to their pre-injury form and function* still eludes us—*if* we critically review our results. This is especially likely when high-energy injuries have resulted in both comminution of the facial skeleton and significant soft tissue damage.

"Key" areas, or sites, considered of great importance in the repair of facial injuries are now well recognised and have been reported widely. There have also been major developments in the fields of tissue healing, biomaterials, and surgical technology, all of which have helped improve outcomes. In many respects, parallels can be drawn with orthopaedic surgery. Management of facial trauma in a sense can be regarded as "facial orthopaedics." Both specialities share the same common core knowledge and apply similar management principles, notably in fracture healing, principles of fixation, and an appreciation of the "soft tissue envelope." However, one would hope that we can additionally draw on our aesthetic skills, as facial surgeons, to get the best possible results in our patients.

Some "Key" Areas in Repair
Medial canthal position
Posterior medial "bulge" of orbital floor
Lateral orbital wall (alignment with greater wing of sphenoid)
Posterior facial height (condyle)
Posterior wall of frontal sinus/dural integrity
Frontal-nasal duct patency
Nasal projection
The zygomatic arch
Occlusion
Wound closure
Soft tissue drape
Anatomical boundaries (e.g., vermillion border, eyebrow)
Lacrimal apparatus
Eyelid margins

The aim of this book is to provide a framework upon which surgeons in training, or those who manage trauma infrequently, can develop skills in assessment, treatment planning, and then (hopefully) repair of facial injuries. Many excellent texts already exist and the aim of this book is to complement these by focussing on the technical aspects. It is of course only a starting point and certainly not intended as a substitute for structured training and experience.

This is a book of "options." As with many areas in medicine and surgery, there are "many ways to skin a cat" and repairing facial injuries is no different. Many injuries can be managed

in more than one way and using more than one method. We have tried to illustrate this. Many techniques outlined in this book will have modifications, or variations. Furthermore, management of some injuries is still very controversial, as we have tried to point out. Although we have endeavoured to cover as much ground as possible, we do accept that this book is by no means totally comprehensive—probably no book ever will be. Nevertheless, we hope this will form a useful foundation for some.

A few quick notes: The images used in this book have been taken over the past decade or so, and perhaps not surprisingly their quality has improved accordingly from those taken with the old-style Polaroid films to the more “state of the art” digital camera. Either way, we hope the quality is sufficient. The references have been chosen on the basis of interest rather than any attempt to be comprehensive. Finally, to get the most out of this book, the reader should ideally have some basic knowledge of anatomy and an understanding of trauma care and basic surgical principles.

Michael Perry
Simon Holmes

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Many people have contributed to this book both directly and indirectly. Without their involvement this would not have been possible.

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Depuy Synthes Medical Ireland, Tekno Surgical, and KLS Martin for providing images of their products and supporting production of this book.

We would also like to thank our past trainers and other colleagues, without whom we may never had developed our interests, skills, and knowledge in trauma care. As Isaac Newton once wrote: "If I have seen further it is by standing on the shoulders of giants."

And, finally, we would like to thank the many hundreds of patients (many of whom remain anonymous) who have so kindly allowed us to use the pictures we have taken. Without them this book would not have been possible and it is to them that we dedicate this book, with our heartfelt gratitude.

June 2014 Michael Perry

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Initial Considerations: High- vs. Low-Energy Injuries and the Implications of Coexisting Multiple Injuries

1

Michael Perry and Steve White

1.1 Introduction

Injuries to the face vary widely in severity. They range from the most trivial to those associated with life-threatening complications. Although in most cases such complications are immediately apparent when the patient is first seen, occasionally they can be concealed, or they can develop gradually over a period of several hours. Airway obstruction from progressive swelling is an example of this. Injuries to the face can either occur in isolation, or they can be associated with significant injuries elsewhere on the patient, some of which may also go unnoticed initially. In some facial or head injuries, sight-threatening complications may also be associated. These, too, may not be immediately obvious. Initial assessment and management can therefore be very challenging, as all these variables need to be taken into account. This is particularly the case following high-energy trauma when multiple injuries are more likely to have occurred.

Unfortunately, the presence of coexisting injuries (or even their suspicion) can have a significant effect on the patient's overall management. Not only can these affect *our* ideal goals in planning treatment, but they can also affect those of other specialties. Even relatively "simple" decisions may not be as straightforward as we would like (*e.g.*, "should we intubate the patient before going to CT, or wait and see what the scan shows?"). Such decision-making is also influenced by local circumstances (available resources, clinical experience, concern for other injuries, and need for transfer).

A team approach is therefore of vital importance, particularly in the early stages of management, when the clinical status of the patient and the need for regular reassessment and intervention are often at their most dynamic. Protocol-driven management is now a well-established concept, and when available, local guidelines should always be followed.

Whenever facial injuries coexist with injuries to the torso, a number of clinical dilemmas commonly arise. A few examples are shown (*see* Table 1.1).

Depending on the injuries present (or even if they are just suspected), one or more of these dilemmas may arise early in the patient's management. As a general observation, the most challenging patients are those with associated head, torso, or spinal injuries, or those patients who present in profound hypovolaemic shock, without an obvious cause. However, even the most "straightforward" of cases can rapidly deteriorate if occult (hidden) injuries remain unrecognised for too long. Injuries to the torso (especially the chest) can significantly affect the timing of surgery, particularly if this is delayed. As surgeons, we need to be aware of all these issues—failure to recognise them may greatly influence outcomes.

Table 1.1 Some common clinical dilemmas when facial injuries coexist with injuries to the torso

Appropriate airway management in restrained supine patients
Management of sudden and unexpected vomiting in restrained supine patients
Clearing cervical spine injuries
"Can I sit up?": the impact of *potential* torso and spinal injuries on allowing patients to protect their own airway
Permissive hypotension and diagnosing facial haemorrhage
Damage control and its effect on the timing of definitive repair
The implications of coexisting skull base or brain injuries
Diagnosing vision-threatening injuries in unconscious patients
Management of the proptosed globe

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1.2 Establishing Clinical Priorities and Triaging Facial Injuries

From our perspective, "emergency care" in facial trauma effectively means airway management, control of profuse bleeding, and the management of vision-threatening injuries (VTI). The management of life-threatening head injuries is outside our area of expertise and requires urgent neurosurgical intervention.

Although true maxillofacial and ophthalmic "emergencies" are uncommon (*i.e.*, complications of facial injuries that require immediate identification and/or management, to preserve life or sight), it is nevertheless important to remember that they can occur any time over a relatively protracted period. They can also occur following relatively minor injuries (*see* Fig. 1.1).

Anticipation is the key to management—some complications may take a while to become clinically apparent. It is therefore important to be aware of early warning signs. It is also important to appreciate the manner in which these complications can potentially affect the patient's overall management. Any risk factors should be identified and noted (*e.g.*, intoxicated patients, or patients taking anticoagulants) (*see* Fig. 1.2).

From a maxillofacial perspective, "emergency care" effectively means

1. Airway management,
2. Control of profuse bleeding and
3. Management of vision-threatening injuries (VTI)

Although head injuries clearly fall within a trauma context, their management is outside our area of expertise, thus requiring the help of our neurosurgical colleagues. These injuries will not be discussed in detail, although an awareness and understanding of their pathophysiology, diagnosis, and management is essential to all trauma physicians.

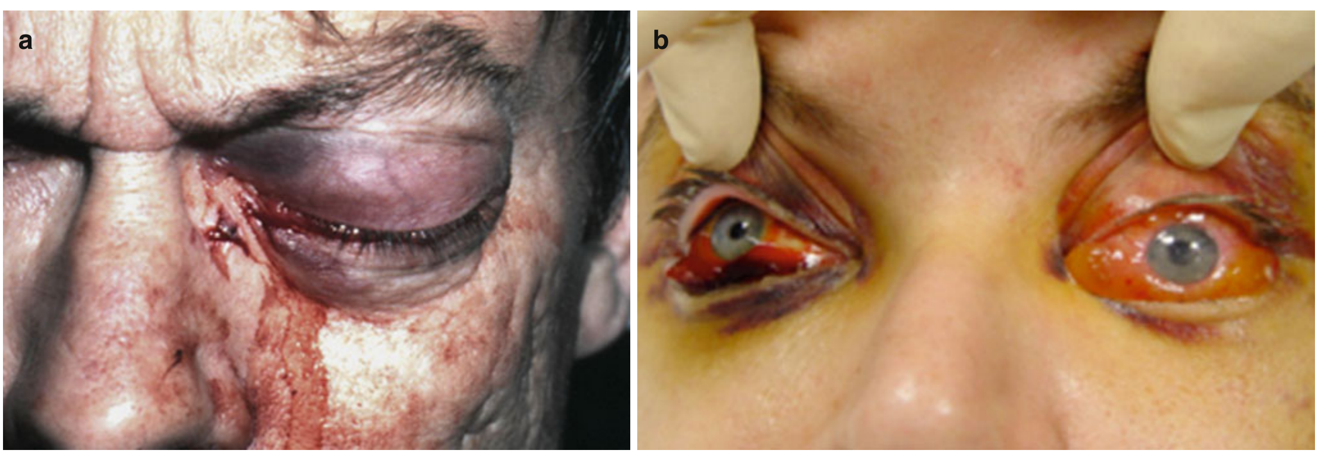


Fig. 1.1 Acute proptosis within 1 h of injury (**a**) and progressive proptosis after 48 h (**b**). Both are vision-threatening, secondary to oedema. The acute proptosis required urgent surgical decompression

Fig. 1.2 Acute proptosis following a penetrating injury, resulting in a retrobulbar haemorrhage (*see also* Fig. 1.51)

Life and sight-threatening complications can occur following apparently trivial injuries. As such they may not be initially considered.

Table 1.2 Triaging facial injuries

Most facial injuries can be placed into one of four groups:
1. **Immediate** life- or sight-saving treatment is required, *e.g.*, surgical airway, control of profuse haemorrhage, or a lateral canthotomy and cantholysis.
2. Treatment is required within **a few hours**. This applies to clinically "urgent" injuries, such as heavily contaminated wounds and some contaminated open fractures (especially skull fractures with exposed dura). The patient is otherwise clinically stable.
3. Treatment can **wait 24 h** if necessary (some fractures and clean lacerations).
4. Treatment can wait **over 24 h** if necessary (most fractures).
Put another way, for each of the above groups, intervention is needed: Within a few seconds Within a few hours Within a few days Within a few weeks

Failure to rapidly recognise and manage any of these emergent conditions can result in loss of life or sight. However, if *none* of these are present, detailed assessment of most facial injuries can usually wait a short while, if necessary. This will enable the comprehensive assessment of the entire patient. All injuries, both above and below the collar bones, need to be rapidly recognised, prioritized, and then managed in a timely and coordinated manner. Unfortunately, priorities can suddenly change, as injuries or other events evolve and become clinically evident (*e.g.*, the development of a compartment syndrome, falling level of consciousness, or unexpected vomiting). Assessment therefore needs to be both systematic *and repeated*, with anticipation of all these potential developments.

From a practical point of view, facial injuries can be broadly placed into one of four groups, based on the urgency of treatment required (Table 1.2).

When assessing injuries above the collar bones, consider them under four main anatomic subheadings:

- The Brain
- The Neck
- The Eyes
- The Face

If there is an obvious injury in one site, ask yourself "Could there be associated injuries in any of the others?" The mechanism of injury may suggest the possibility of occult injuries that may need further detailed investigation (discussed later) (*see* Figs. 1.3 and 1.4).

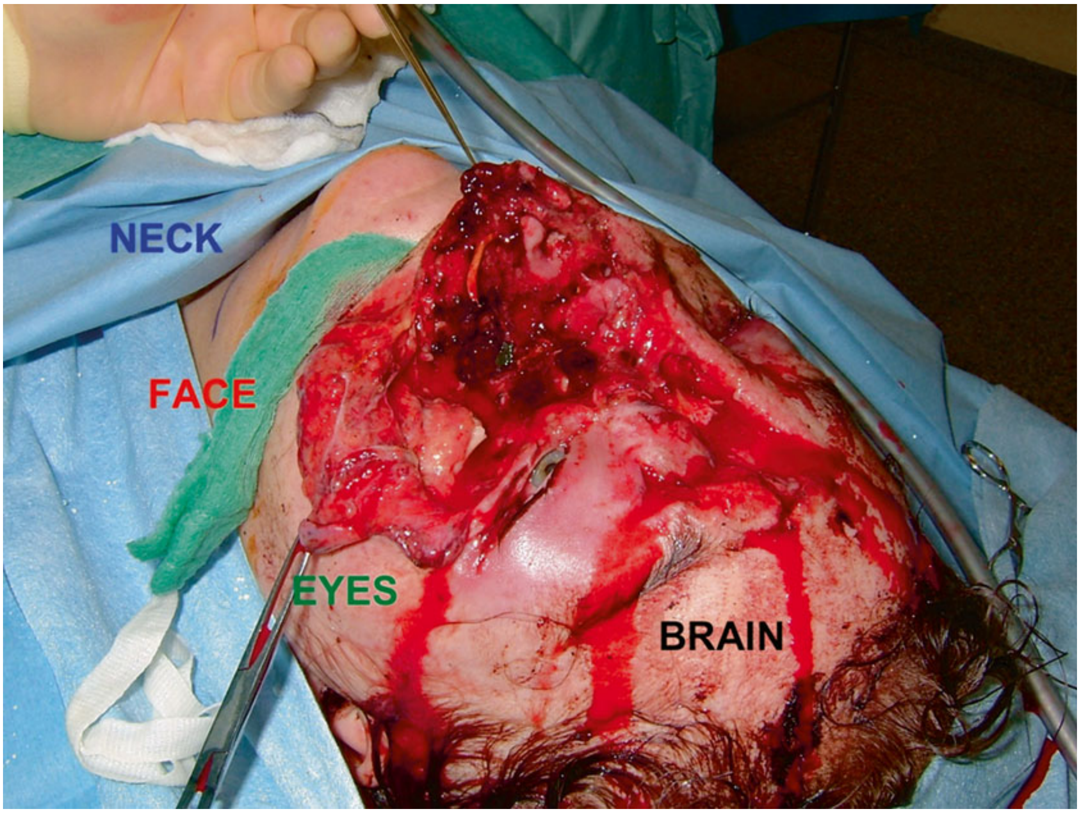


Fig. 1.3 Obvious facial injuries following a high-speed motor vehicle collision. The brain, eyes, and cervical spine require careful evaluation

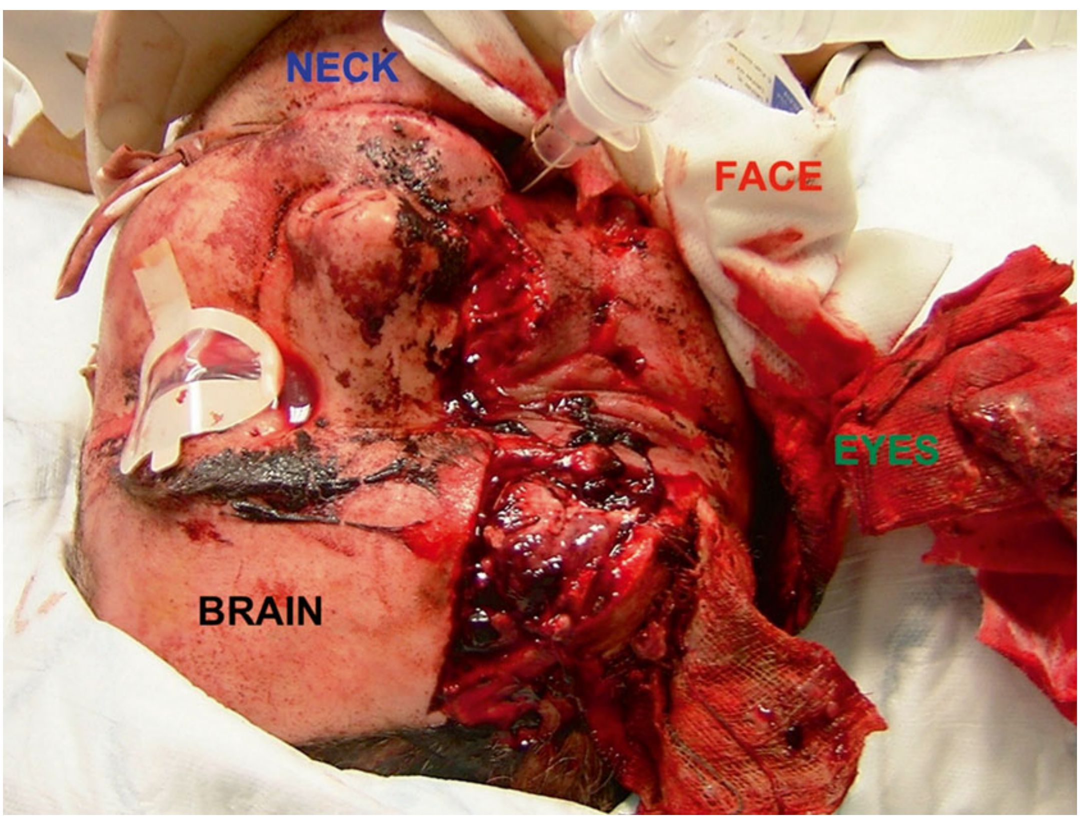


Fig. 1.4 Obvious injuries to the face and forehead with exposed brain and rupture of the globe. Remember the cervical spine as part of the assessment

1.3 Advanced Trauma Life Support™ and Facial Injuries

> Facial surgeons should ideally be an integral part of the trauma team when facial injuries are evident. Advice or interventions are frequently required. This is particularly relevant in the management of:
> 1. The airway
> 2. Hypovolaemia and facial bleeding
> 3. Craniofacial injuries
> 4. Initial assessment of the eyes

Advanced Trauma Life Support (ATLS™) has generally become accepted as the gold standard in the initial management of the multiply injured patient and is now taught in more than 50 countries worldwide. It is based on a number of well-established principles (*see* Table 1.3).

Resuscitation and management of life-threatening injuries are undertaken as quickly as possible; hence the term "golden hour." However, there is no evidence to show that survivability rapidly declines specifically after 60 min. The term "golden hour" is simply an expression used to highlight the need for rapid intervention—time is of the essence. Understanding the mechanism of injury is another very useful concept. This helps us suspect the presence of occult injuries. "Deceleration" injuries (when the patient comes to an abrupt stop) are a good example of this. Interestingly, this understanding of the mechanism of injury is not new. Hippocrates is reported to have first noted the association between blunt facial trauma and blindness around 400 BC, while in 1557, Vesalius noted disruption of the thoracic aorta in a man following a fall from a horse.

Advanced Trauma Life Support™ provides a systematic approach that should ensure that life-threatening and subsequent injuries are identified and managed in an appropriate and timely manner. Unfortunately, when injuries to the face coexist in the multiply injured patient, decision-making may not be as simple as we would like. This is for several reasons:

1. ***Clinical priorities can conflict***. Following completion of the primary survey (a rapid process aimed at "treating the greatest threat to life first"), all the patient's injuries (and clinical developments) then require further evaluation and definitive management. These may be difficult to prioritise, particularly in patients who have sustained significant facial injuries. Two examples are given in Tables 1.4 and 1.5.
2. ***Clinical priorities can suddenly change***. The patient's blood pressure, oxygen saturation, or Glasgow coma scale (GCS) may suddenly fall for no obvious reason. This requires immediate reassessment. Unexpected vomiting during transfer, or in the radiology department or computed tomography (CT) scanner, is potentially a common problem in all patients with facial injuries. But does this mean that the airway should be secured in all patients *just in case* they vomit? If so, when should they be extubated? This consideration would need to include patients with relatively minor facial injuries as well as those who are just clearly intoxicated.
3. ***Clinical priorities can be hidden***. This is particularly relevant in the mediastinum and retroperitoneum following deceleration injuries. Some injuries (*e.g.*, carotid and upper aerodigestive tract), are relatively uncommon and therefore may not be initially considered in the emergency department. Cardiac contusion following chest trauma can be misdiagnosed as musculoskeletal pain. Yet all these injuries (and many others) carry significant morbidity and mortality if missed. From a maxillofacial

Table 1.3 Advanced trauma life support™ principles

ABCDEs of assessment (***A***irway control with cervical spine protection, ***B***reathing with ventilation, **C**irculation with haemorrhage control, **D**isability—neurological status, and **E**xposure/**E**nvironment)
"Primum non nocere" (first, do no harm)
The concept of the "golden hour"
The need for frequent reassessment, for evolving injuries
The importance of the mechanism of injury

Table 1.4 Clinical dilemma 1

What is the best way to manage an alert patient with significant facial injuries (placing the airway at risk), who repeatedly wants to sit up, but who (based on the mechanism of injury), may *possibly* have spinal or pelvic injuries?
Option 1. Endotracheal intubation would secure the airway, but results in loss of the ability to regularly reassess the patient clinically (level of consciousness/can they still see?/is the abdomen becoming tender?/could they be developing a compartment syndrome?/can they "wiggle" their toes?)
Option 2. Maintaining the airway in an immobilised patient facilitates repeated clinical assessment, but places them at risk from unexpected and sudden vomiting.
Option 3. Sitting the patient up (to protect the airway) puts the spine at risk and may displace pelvic fractures.

Table 1.5 Clinical dilemma 2

How do we manage a "stoney hard" proptosis in a patient requiring immediate laparotomy?
Option 1. Should surgical decompression be attempted in theatre in the absence of a precise diagnosis (bearing in mind that time is against us)?
Option 2. Should surgery be deferred until CT scans of the orbit have been done? (Is the proptosis secondary to blood, bone, air, oedema or frontal lobe herniation? Are there any mobile bone fragments around the orbital apex?)

perspective, how do we rapidly diagnose (or perhaps more pertinently, confidently *exclude*) a vision-threatening injury requiring immediate intervention, or blindness in the unconscious patient?

It is not just patients with major facial injuries that present these dilemmas. Those with relatively *minor* facial injuries can still be problematic due to poor cooperation, vomiting, or simply being too intoxicated to assess thoroughly. Alcohol, brain injury, and facial bleeding are commonly associated with facial injuries in many countries. Potentially these can result in major problems if the patient vomits unexpectedly while under spinal immobilisation and inadequate supervision.

These are just a few clinical scenarios we may have to deal with when treating patients with multiple injuries and injuries to the face. For most scenarios there is usually no right or wrong answer. Many factors need to be taken into consideration and the pros and cons of each option quickly considered. Experience is extremely valuable and one should never be reluctant to seek it.

Many heads are better than one—a team approach is invaluable.

> Facial injuries complicate the overall management of the multiply injured patient because they present their own set of clinical priorities. These need to be carefully balanced against actual *or potential* injuries elsewhere, some of which may take greater priority. Injuries elsewhere may greatly influence the management of facial injuries, notably timing of definitive repair.

1.4 Understanding Mechanisms of Injury

> The possibility of delayed onset of life-threatening complications is particularly important when interhospital transfers for specialist treatment is being considered.

Knowing the mechanism of injury in a trauma patient is very helpful during initial assessment. Often it can provide important clues to the possibility of associated and sometimes occult injuries. Up to 15 % of all injuries (particularly spinal and orthopaedic) have been reported to go unrecognised following initial assessment. Some autopsy studies have shown an even higher percentage. Specific injury patterns are now well known to be associated with certain injuring mechanisms. A few examples of these are listed in Table 1.6.

Table 1.6 Interpreting mechanisms of injury

A fall from a height of ≥10 ft carries an increased risk of sustaining spinal, pelvic, and long-bone injuries.
Anteroposterior crushing forces can result in mediastinal compression ("shoveling effect" or "osseous pinch").
Deceleration injuries can result in shearing forces across pedicled viscera, which can tear. In the thorax (mediastinum) this is known as the "bell clanger" effect. Calculations have shown that a surprisingly low instantaneous deceleration has the potential to kill due to this effect; viscera and organs can partially or totally avulse their vascular pedicles, resulting in catastrophic haemorrhage.
Blast injuries can result in tension pneumothorax or major pulmonary contusions, even in the absence of external signs of injury.
Blunt trauma to the forehead can result in blindness, even in the absence of fractures.
A blow directly on the chin can result in the well-known "guardsmans" fracture, or an injury to the brain stem.
Anterior-posterior–directed forces to the face can result in hyperextension injuries to the cervical spine and spinal cord injury (notably in the elderly)
Many other examples exist. Crudely speaking, injuries occur as a result of varying combinations of compression, distraction, overpressure, cavitation, and shearing forces.

Unfortunately, some injuries may not be *immediately* apparent and can take hours, or even days, to become clinically detectable (*see* Figs. 1.5 and 1.6). Aortic dissection, for instance, can remain relatively symptom free initially, only to kill the patient a few days later. Delayed onset of these life threatening complications is particularly important when interhospital transfer to specialist units is being considered.

Fig. 1.5 This elderly patient was seen as an outpatient, having tripped and fallen flat on her face. In addition to her facial injuries she was also complaining of some mild weakness in her right hand. MRI confirmed a central cord syndrome. The clue is the mechanism of injury, which resulted in hyperextension of the neck

Fig. 1.6 Angiogram demonstrating a tear in the aorta. This occurred following a deceleration injury. Rapid deceleration can result in life-threatening mediastinal injuries

For these reasons, many life-threatening injuries (notably mediastinal), are now actively screened for, rather than adopting a "wait-and-see" policy. In many trauma centers, indications for imaging (usually CT) now include the mechanism of injury, in addition to clinical signs. Clinical examination of the chest and abdomen is generally accepted as unreliable in the trauma setting and imaging is now frequently undertaken. However, this may result in the need to urgently transfer patients with facial injuries out of the relative safety of the emergency department, potentially with an "at risk" airway, or unrecognised facial bleeding. The risks and benefits of urgent intubation prior to transfer therefore need to be quickly weighed up.

Fortunately, with the newer high-speed scanners currently available, CT of the facial bones should now be possible at the same time as CT imaging elsewhere on the patient. Only in those patients requiring immediate life-saving interventions should this be deferred. Imaging of the face along with the rest of the torso avoids further transfers later on. It also avoids potential delays in the diagnosis, planning and subsequent treatment of the facial injuries.

1.5 Initial Assessment in Facial Trauma

All clinicians involved in trauma management should be competent in carrying out a primary survey and initiating resuscitative procedures. When facial injuries are present, this particularly involves specialist airway management and control of facial bleeding. Early consideration of vision-threatening injuries is also important, but this should not distract from the initial assessment and resuscitation.

1.5.1 Airway, with Control of Cervical Spine

In all trauma patients, the first priority is to quickly assess the airway, while at the same time protecting the cervical spine (*see* Table 1.7).

During assessment, the cervical spine should be immobilised, either manually by an assistant, or by using a hard collar, blocks, and straps. However, combative patients may only tolerate a hard collar. Forceful restraint of the head in a thrashing patient simply creates a fulcrum with leverage on the neck as the rest of the body moves. In such cases, if the patient does not quickly settle with oxygenation, correction of hypovolaemia and pain relief, then formal anaesthesia with intubation and ventilation must be considered. This is considered safer than sedating the patient without providing definitive airway control.

It is important to remember that the "airway" is not just the mouth. Obstruction may occur at any point from the lips and nostrils to the carina. Many factors can contribute to airway compromise, notably a fall in the consciousness level. This is most commonly associated with alcohol and brain injury. Obstruction may arise from foreign bodies (food, dentures, teeth, blood and secretions) or displaced/swollen tissues. The most common obstructing materials in facial injuries are blood and vomit. Trauma to the front of the neck (bicycle injuries, automobile crashes, falls, sports injuries, clothesline injuries, and hanging) can also result in direct injury to the upper airway and occasionally expanding haematoma.

Obstruction is an ever-present risk in almost all patients with significant facial injuries. Blood and secretions can collect in the pharynx, especially when they are supine. In most awake patients, this is simply swallowed. However, when midface or mandibular fractures are present, swallowing may be painful and ineffective in keeping the airway clear. Early signs of partial obstruction may be easily overlooked, particularly in patients who are intoxicated or have an associated brain injury. Not only are these patients at risk of vomiting, but any reduction in consciousness further impairs protective airway reflexes. Care must be taken if these patients are positioned supine.

Table 1.7 Airway assessment following facial injury

This usually starts by trying to elicit a verbal response: "what happened?" or "how do you feel?"
Although an appropriate reply is encouraging, direct inspection of the oropharynx for bleeding or loose or foreign bodies is still important (after all, most of us can easily talk with food or chewing gum in our mouths).
Significant bleeding may not be obvious in the supine patient if they are awake enough to swallow their blood. This will only be recognised by direct inspection of the pharynx—take a good look.
Retropharyngeal haematoma (secondary to a cervical spine injury) can occasionally result in airway obstruction. If it is present, consider the possibility of an unstable fracture.
Any suctioning of the pharynx should be undertaken carefully in awake patients. Stimulation of the soft palate and pharynx can trigger vomiting.
Consider the mechanism of injury to the face—is major swelling likely to occur?
Is the mandible intact, or is there loss of tongue support?

It is therefore important to identify oral or nasal bleeding early, even in the alert patient. If not, swallowed blood will accumulate in the stomach, resulting in nausea and a risk of unexpected vomiting (perhaps later on, when the patient is less well attended by staff). Alcohol intoxication complicates matters further as it is well known to result in loss of consciousness and vomiting.

It is important to identify oral or nasal bleeding even in the alert patient. If not, swallowed blood will accumulate in the stomach, resulting in nausea and a risk of unexpected vomiting.

1.5.2 "Can I Sit Up?"

Patients should never be forced or restrained onto their backs—this is more likely to compromise both the airway and any spinal injury.

When facial injuries are present in supine patients (and sometimes when they are not), it is important to recognise the implications of repeated requests or attempts by the

patient to sit up. Although agitation is a common cause, attempts to get up may also indicate a desire to vomit, or that there is partial airway obstruction from foreign bodies, swelling, loss of tongue support or bleeding. Patients may try to sit themselves forwards and drool, thereby allowing blood and secretions to drain from the mouth (*see* Fig. 1.7).

However, this position is clearly at variance to ATLS teaching: “Proper immobilisation is achieved with the patient in the neutral position, *i.e.*, supine without rotating or bending the spinal column.” “Cervical spine injury requires continuous immobilisation of the entire patient with a semirigid cervical collar, backboard, tape and straps before and during transfer to a definitive care facility.” Patients may therefore arrive in the emergency department securely strapped to a spine board. If the straps are released and the patient is allowed to sit up, this will axially load the spine and pelvis, potentially displacing fractures. This loading will occur even if the head is supported. The dilemma here is, when is it safe to allow this? And if it is not safe, what should be done (and how soon)? (*see* Fig. 1.8.)

Whether to allow such patients to sit up (or not) therefore depends on a number of factors that need to be carefully and quickly weighed up (*see* Table 1.8).

Careful assessment and a degree of judgment are required in all patients with *apparently* isolated, but significant facial injuries. The decision to allow these patients to sit up is based on a “risk-benefit analysis,” *i.e.*, the risks and benefits of keeping the patient supine with potential airway obstruction versus the risks and benefits of axial loading of a *possible* spinal injury.

Combative patients with obvious facial injuries who refuse to lie down may initially require management on their side (following careful log-rolling). This is not the best position to maintain during assessment and management, but it is possible in some patients. This also requires an element of judgment. Although the spine is not formerly immobilised, the main consideration under these circumstances is to do no further harm (which may occur by restraining them). Alternatively some patients may be allowed to sit up (other injuries permitting). However, the head still needs to be supported to minimise movement. If possible a hard collar should be applied.

In those patients who cannot sit up or be logged-rolled, two critical decisions are therefore necessary:

1. Does the airway need securing? (*i.e.*, anaesthesia and intubation) and
2. If so, how urgently?

Not all patients with facial injuries develop airway obstruction. Furthermore, following anaesthesia, loss of contact precludes further clinical evaluation (notably level of consciousness). This often results in the need for urgent CT scanning, which may otherwise have been avoided if the patient was awake and could have been assessed clinically. On the other hand, all supine patients can potentially vomit unexpectedly and therefore need to be kept under close observation.

Fig. 1.7 This patient received a localised blow to the face when the door of a lorry swung round and struck him. He was walking around at the scene with significant facial bleeding, when the paramedics arrived. A good example of “primum non nocere”—if he had been placed supine his airway could have obstructed

Consequently for all supine patients, there should be a clear plan of how to manage vomiting should it suddenly occur. Ideally, a senior experienced anaesthetist, or other clinician trained in advanced emergency airway management, should be present during the assessment of these potentially problematic patients. A “difficult-intubation trolley” should also be readily available in the resuscitation room.

Whatever the circumstances, all efforts should be made to protect the cervical spine as best as possible. This requires the minimum of manual in-line immobilisation, but ideally a

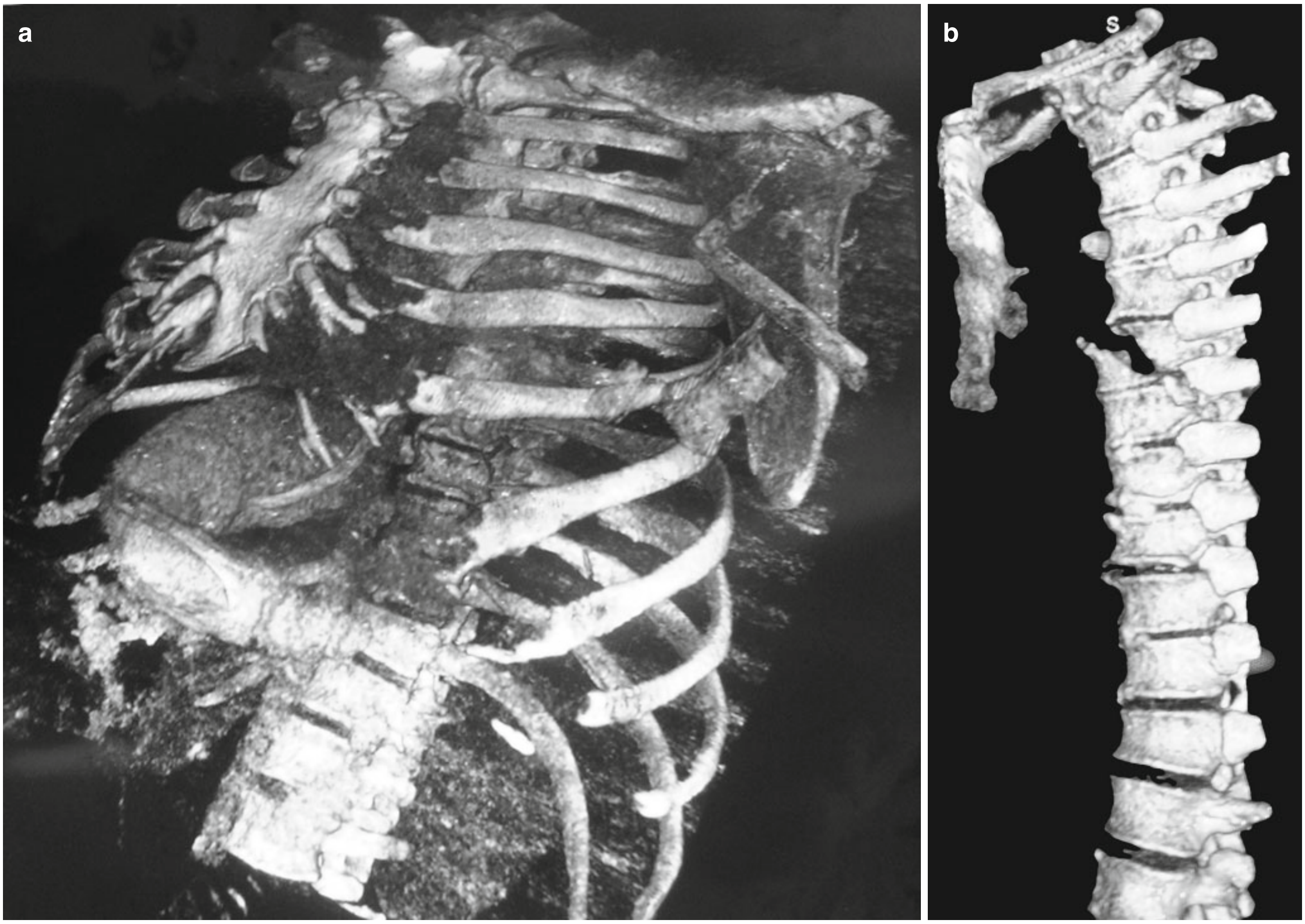


Fig. 1.8 Multiple rib fractures (**a**) and a vertical split in a thoracic vertebra (**b**) following a crush injury. This patient required spinal immobilisation and certainly would not have been able to sit up if coexisting facial injuries were obstructing the airway. This would have required urgent intubation

well-fitting hard collar, blocks and straps should be applied. Hard collars should fit properly, particularly in patients with mandibular fractures. If they do not, the fractures may be displaced further. However, hard collars have also been reported to exacerbate intracranial hypertension in patients with severe head injury. In such cases, other measures to immobilise the neck may be appropriate (the patient will be unconscious and therefore unlikely to move their own head).

> Cervical spine injuries need to be "cleared" as soon as possible, particularly if anaesthesia and intubation are required. This can be especially difficult in the presence of alcohol intoxication, brain injury, opiate administration, or distracting facial injuries.

Table 1.8 "Can I sit up?"

Consider the following:
Is the patient just agitated or intoxicated, or is this a sign of partial airway obstruction?
Mechanism of injury: is this an isolated facial injury, or could there be spinal, torso, or pelvic injuries?
Is the airway at risk from an easily treatable cause (foreign body, mobile fracture), or a complex cause? (Impacted midface, active bleeding)
Is the face/airway swollen and if so, is it likely to get worse?
Is there significant, ongoing facial haemorrhage?
Is imaging outside the resuscitation room likely to be required (transfers)?
Is the clinical scenario likely to deteriorate? (swelling/head injury/drugs)
Who is helping me?

1.5.3 The Significance of Facial Fractures and Effects of Soft Tissue Swelling on the Airway

1.5.3.1 Mandible Fractures

Loss of tongue support and significant swelling of the floor of the mouth may occur in patients with bilateral ("bucket handle") or comminuted fractures of the mandible. These tend to follow relatively localised, but high-energy impacts (*see* Figs. 1.9 and 1.10).

In alert patients, self-control of the airway may still be possible, even if they are supine. However, it is not secure and these patients should not be left unattended if they are restrained. In the presence of coexisting head injuries or intoxication, loss of tongue control and other protective reflexes may rapidly become a problem (even if there are no fractures). Comminuted (and therefore high-energy) fractures of the mandible carry a significant risk to the airway, not only from loss of tongue support, but also from significant soft tissue swelling and intraoral bleeding, which commonly occur (*see* Fig. 1.11). Anaesthesia and intubation should therefore be considered early. If this is withheld, the patient's airway must be reassessed frequently. With the more simple (low-energy) anterior fractures, temporarily reduction and stabilisation may be possible by placing a "bridle wire" around the adjacent teeth. This can usually be done under local anaesthesia and is described elsewhere. A bridle wire reduces bleeding from the torn mucosa, and by supporting the fracture enables the patient to swallow more effectively.

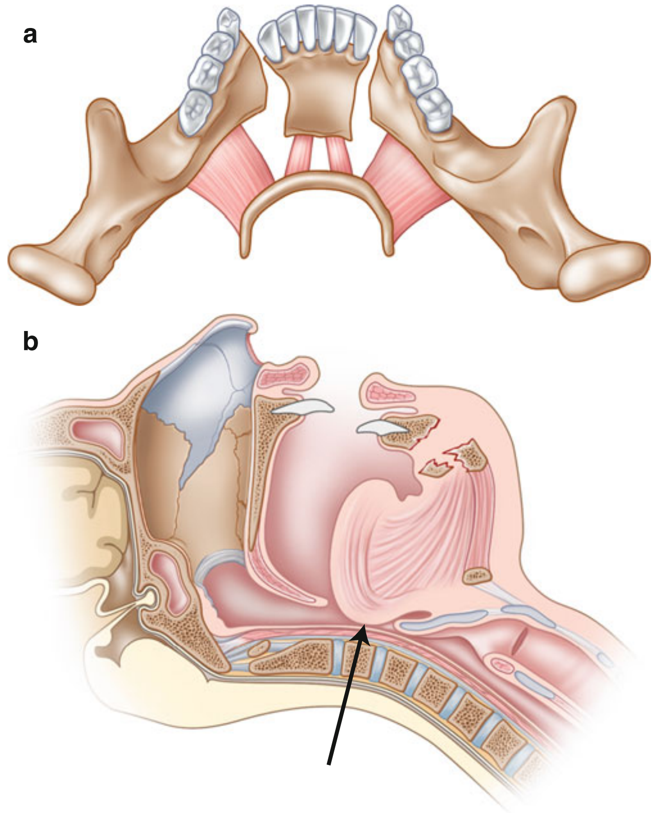


Fig. 1.9 "Bucket handle" or comminuted fractures of the mandible place the airway at risk. The tongue is attached to the central mobile fragment(s) (**a**). If the patient is supine, any displacement can allow the tongue to fall back and obstruct the upper airway (**b**). Snoring is a sign of impending obstruction

1.5.3.2 Midface Fractures

Occasionally, collapsed midface fractures may cause airway obstruction. High-energy impacts to the relatively fragile "middle third" of the face may result in comminution of the bones. These can crumple backwards and downwards along the inclined surface of the relatively thick skull base, resulting in impaction of the soft palate into the pharyngeal space, further swelling, and increasing obstruction. In addition, there is usually significant bleeding, which further contributes to the patient's airway problems (*see* Fig. 1.12).

Functionally the facial skeleton can be regarded as a "crumple zone", due to the presence of its sinuses. In some respects this arrangement can be considered as functioning like an airbag or chassis of a car, absorbing much of the impact energy which would otherwise have been transferred to the driver (brain). Whether this is of evolutionary significance is not known.

1.5.3.3 Combined Fractures

When both midface fractures and mandibular fractures occur at the same time (sometimes referred to as "panfacial" fractures), there is a very high risk of airway compromise. In addition to the problems just mentioned, these injuries often bleed profusely and may soon develop significant swelling. Patients may also have associated brain injury, as these fractures occur following high-energy impacts. These types of injury emphasise the need for regular repeated assessments. Airway obstruction, unexpected vomiting and hypovolaemia from unrecognised bleeding are all common consequences, none of which may be read-

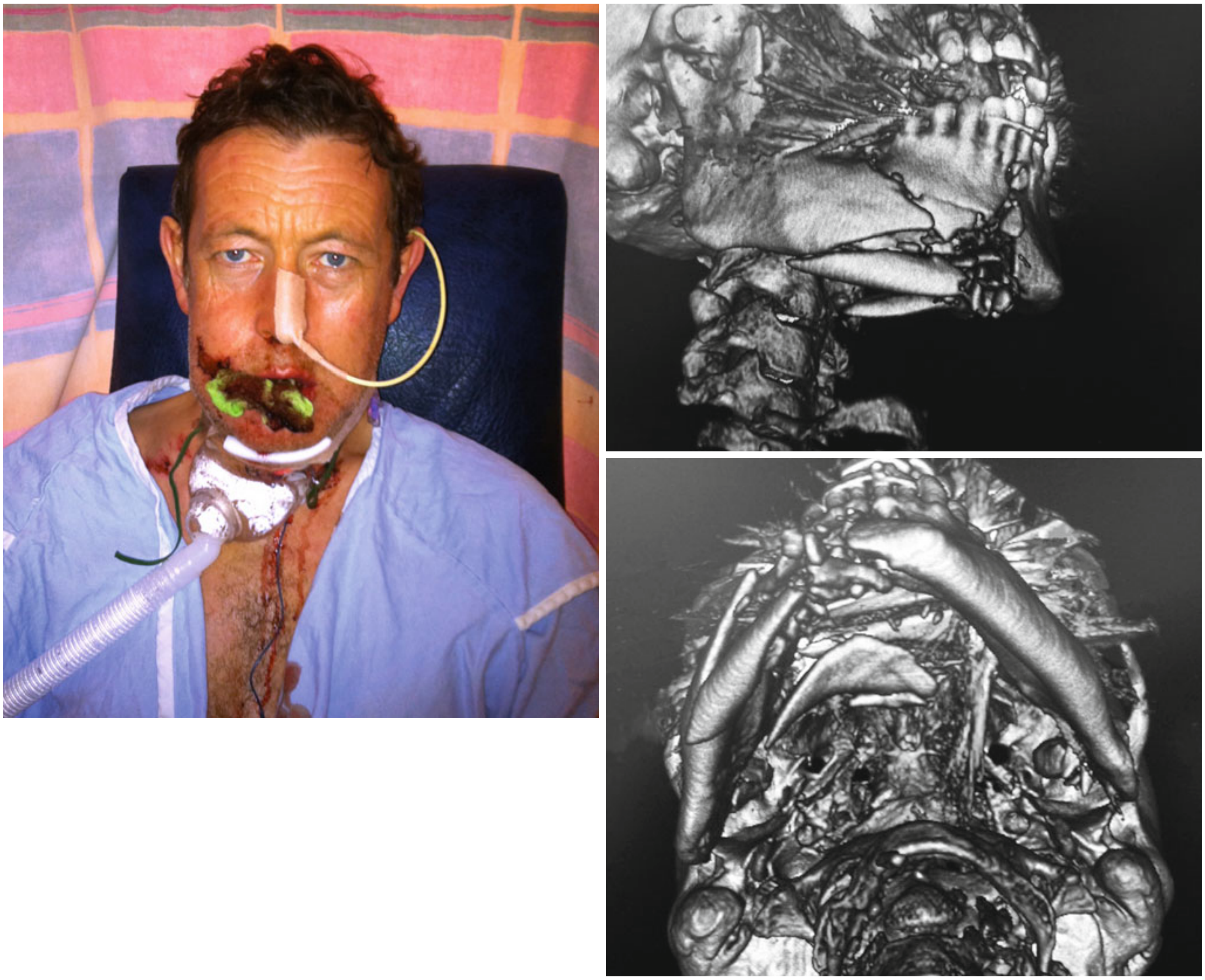


Fig. 1.10 This patient was kicked in the face by a horse, sustaining comminuted fractures of the mandible. He developed airway-threatening swelling over the next few hours, which required urgent intubation and placement of a temporary (percutaneous) tracheostomy, prior to repair

ily apparent or expected on initial presentation. Significant soft tissue swelling inevitably occurs following such high-energy injuries and often necessitates prolonged intubation or planned elective tracheostomy. The role of steroids in the acute management of facial trauma has not been established and their use may be contraindicated in the presence of brain injury.

Usually it is the mechanism of injury, not the fracture pattern, that is most reliable in predicting swelling (*see* Figs. 1.13 and 1.14).

Significant swelling can occur in patients with relatively minor "cracks" of the facial skeleton. It can also occur in the absence of fractures—notably in patients taking anticoagulants, those with clotting abnormalities, and the elderly. Swelling can take several hours to occur. Clinicians therefore need to be wary and regularly re-examine the patient. Stridor is a particularly worrying sign and often requires urgent intubation.

Fig. 1.11 Resolving sublingual haematoma 1 week following mandibular fracture. Patient was on warfarin (International Normalized Ratio [INR] 6 on presentation) with partial airway obstruction. Management included urgent fiberoptic intubation, correction of INR, incision and drainage of haematoma and repair of fracture

Retropharyngeal haematoma may indicate an underlying cervical spine fracture as well as result in airway obstruction. Fractures of the hyoid bone (seen on the lateral cervical spine film) should be regarded as a "marker" of significant injury, indicating risks of obstruction.

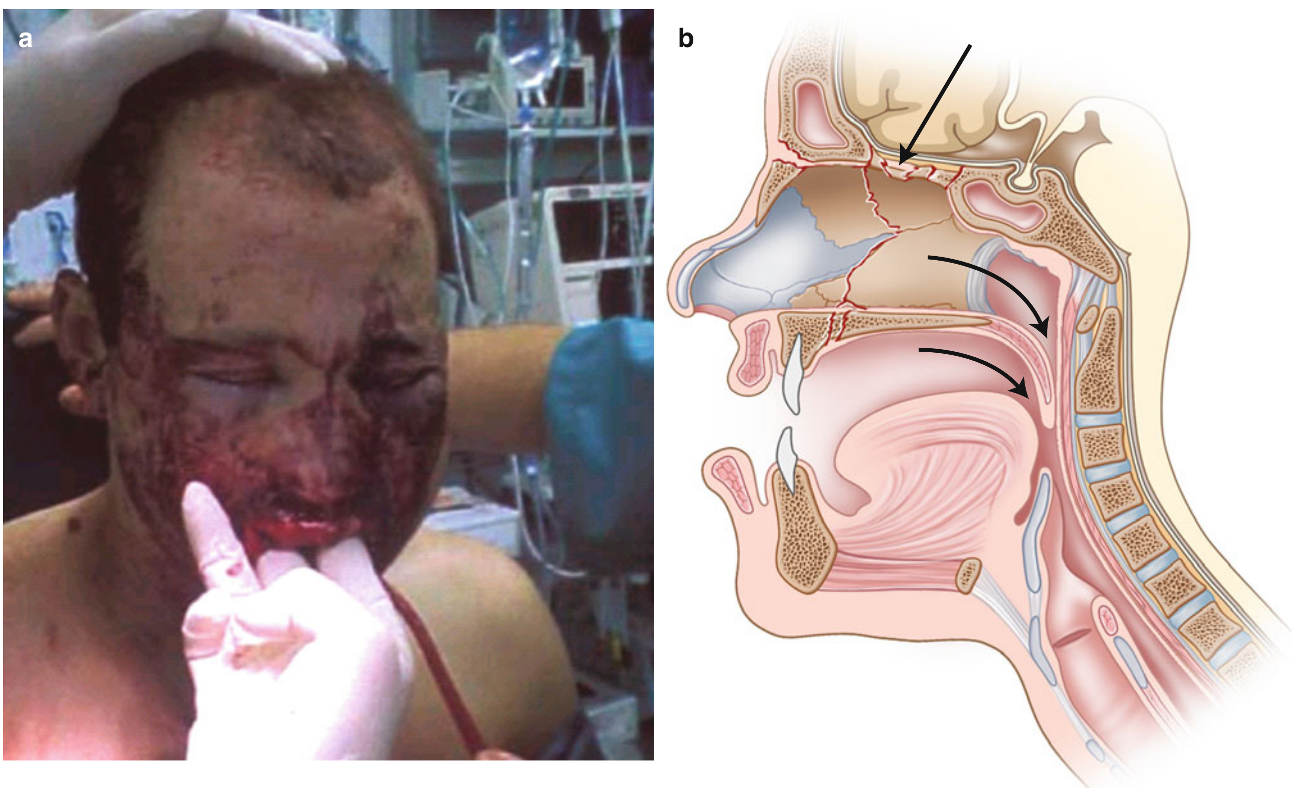


Fig. 1.12 This patient had severe midface fractures that were very mobile (**a**). Collapse of the soft palate together with swelling can result in airway obstruction (**b**). The patient was found at the scene of injury protecting his own airway by leaning forward. The maxilla is being gently repositioned to maintain the airway and control haemorrhage. This patient required urgent intubation to enable full control of the haemorrhage and protect the airway from progressive swelling (already evident)

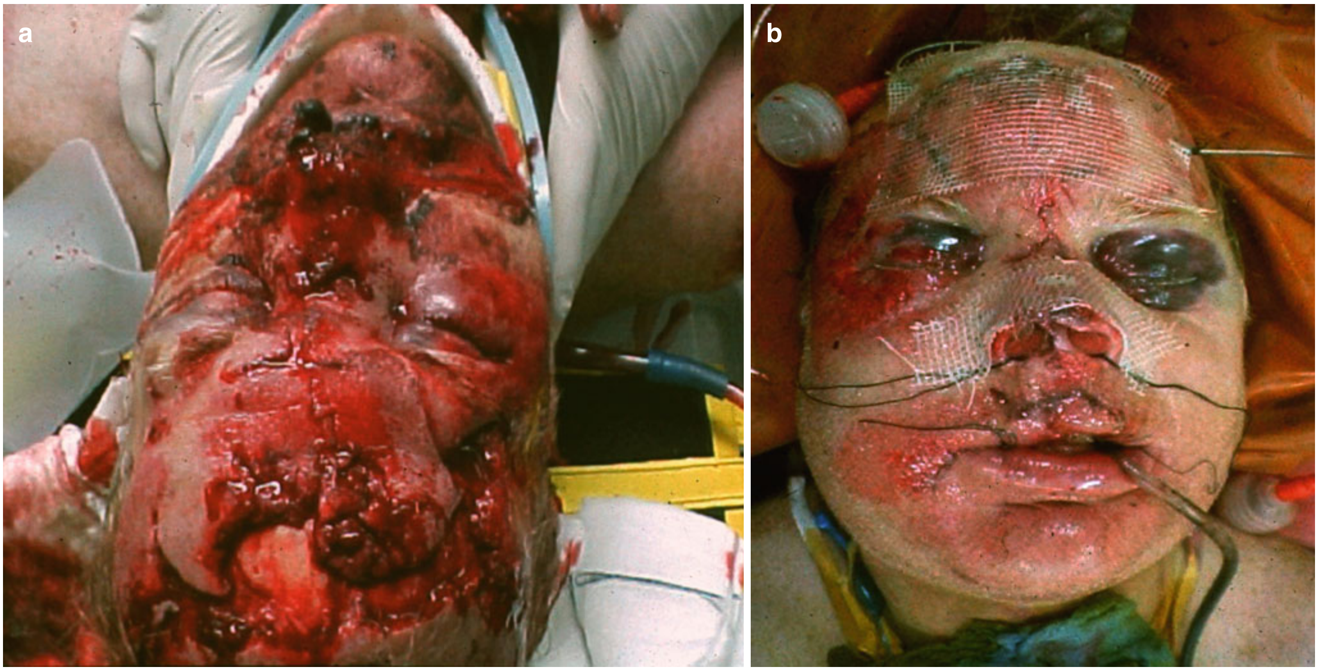


Fig. 1.13 These two views are of the same patient initially on arrival in the emergency department (**a**) and 24 h later (**b**). There has been a huge amount of swelling overnight. This was anticipated in view of the mechanism of injury. The patient was intubated in the emergency department and a tracheostomy performed after further assessment of all injuries

Fig. 1.14 Progressive facial swelling following isolated midface fractures. The mandible is intact. This patient is being nursed on her side but will require very close observation for the next 24 h

1.5.4 The Anterior Neck

This anatomical site can be easily overlooked during initial assessment (particularly when the patient has a hard collar on), but requires careful and regular examination. If the patient arrives with a collar on and an injury here is suspected, the collar should be unfastened and the anterior neck examined, while an assistant maintains in-line manual immobilisation. The anterior neck can be regarded as a watershed between "Airway" and "Breathing"—life-threatening problems in both (and occasionally "circulation") can manifest clinical signs here (*see* Table 1.9).

Injuries to the larynx can quickly swell and result in airway obstruction. A hoarse voice, haemoptysis, surgical emphysema, and fracture crepitus in the neck are highly suggestive of a serious injury and should be actively looked for. Motorcycle helmet wear, strangulation, and contact sports are important clues from the history. It is important to carefully palpate the great vessels, hyoid, and larynx for signs of injury and to look for external swelling (which may reflect internal swelling). Surgical emphysema and distended neck veins may also indicate a thoracic problem that needs to be urgently evaluated (*see* Fig. 1.15).

Table 1.9 Useful clinical signs in the anterior neck

Tracheal deviation or separation
Laryngeal tenderness or crepitus
Hyoid tenderness
Surgical emphysema
Distended neck veins
Open wounds
Significant swelling

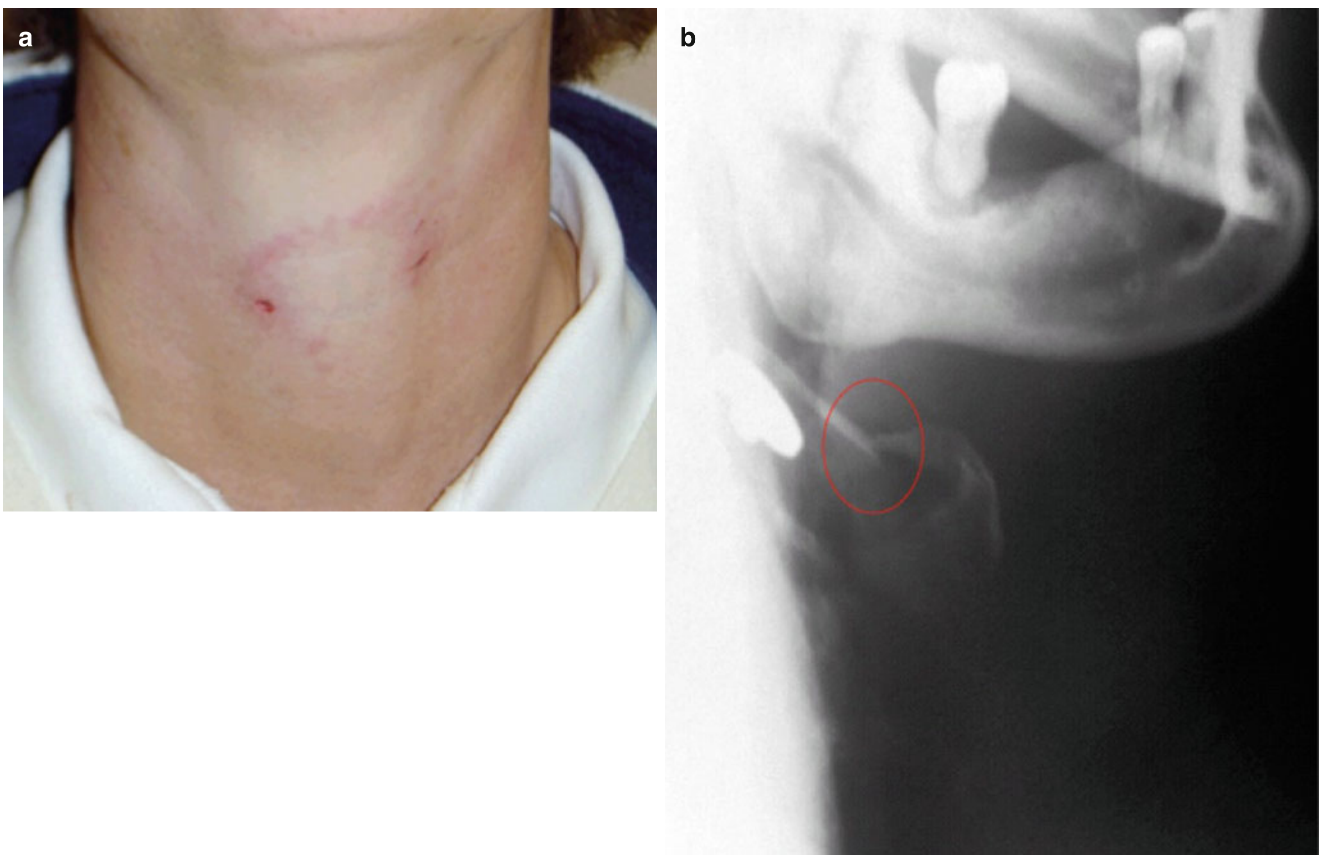


Fig. 1.15 The anterior neck is often overlooked in the initial assessment of the multiply injured patient. In this case it was not. The patient was bitten in the neck by a dog (**a**). There is a fracture of the hyoid bone, as shown in the radiograph (**b**)

1.6 Airway Management in Facial Trauma

1.6.1 Initial Measures

All trauma patients should receive oxygen. In supine patients, the risk of obstruction should always be anticipated. The ability to maintain the patient's own airway may become increasingly difficult and can suddenly be lost. Whether or not this occurs depends on several factors (notably the severity of the facial injuries), but once the airway has been lost it can be very difficult to rapidly secure it. With severe injuries there may be mobile, bleeding fractures, and swelling can develop quickly. Early assistance from an experienced anaesthetist is therefore essential. Occasionally, a surgical airway may be required. This is more likely when there is gross swelling from extensive injuries, or an inability to intubate the patient. Members of the trauma team should therefore be competent in performing this procedure if it is urgently required. So should facial surgeons.

Several well-known techniques exist for initially maintaining an airway (*see* Table 1.10).

It is important to appreciate that maintaining an airway is not the same as securing it. Patency can still be lost. High-volume suction (using a wide bore, soft plastic sucker) should always be readily available to clear the airway of blood and secretions, taking care not to induce vomiting. Any loss of the gag reflex during suctioning should prompt consideration of the need for early endotracheal intubation.

Table 1.10 Airway maintenance techniques in trauma

Suction
Jaw thrust (keeping head in neutral position)
Chin lift (keeping head in neutral position)
Oro- and nasopharyngeal airways
Tongue suture
Laryngeal mask

The jaw thrust and chin lift are commonly used techniques, but these may be difficult to do (although not impossible) when there are multiple fractures of the mandible. Care must also be taken not to distract any fractures as this is not only painful, but results in further swelling and blood loss, and can tear mucosa (*see* Fig. 1.16).

In trauma, the chin lift is a two-person technique. The head is not extended into the "sniffing position" as it would normally be (remember the cervical spine). An assistant is therefore required to support the head. Even with such support (and a hard collar) both the chin lift and jaw thrust have been shown to produce a small amount of movement of the cervical spine. They must therefore be performed very carefully.

If the patient is unconscious and has severe injuries with complete loss of tongue support, a tongue suture or pointed towel clip may facilitate suctioning and intubation. Remember that this technique itself may cause bleeding (*see* Fig. 1.17).

If the midface has been impacted posteriorly, it may need to be repositioned to improve the airway. Grasping the premaxilla and gently pulling it forward achieves this. The movement does not require much force, but is often uncomfortable for the patient. It must also be undertaken with protection of the cervical spine. Sometimes the maxilla hangs loose and needs to be gently lifted. Repositioning the maxilla not only improves the airway but reduces blood loss (*see* Fig. 1.18).

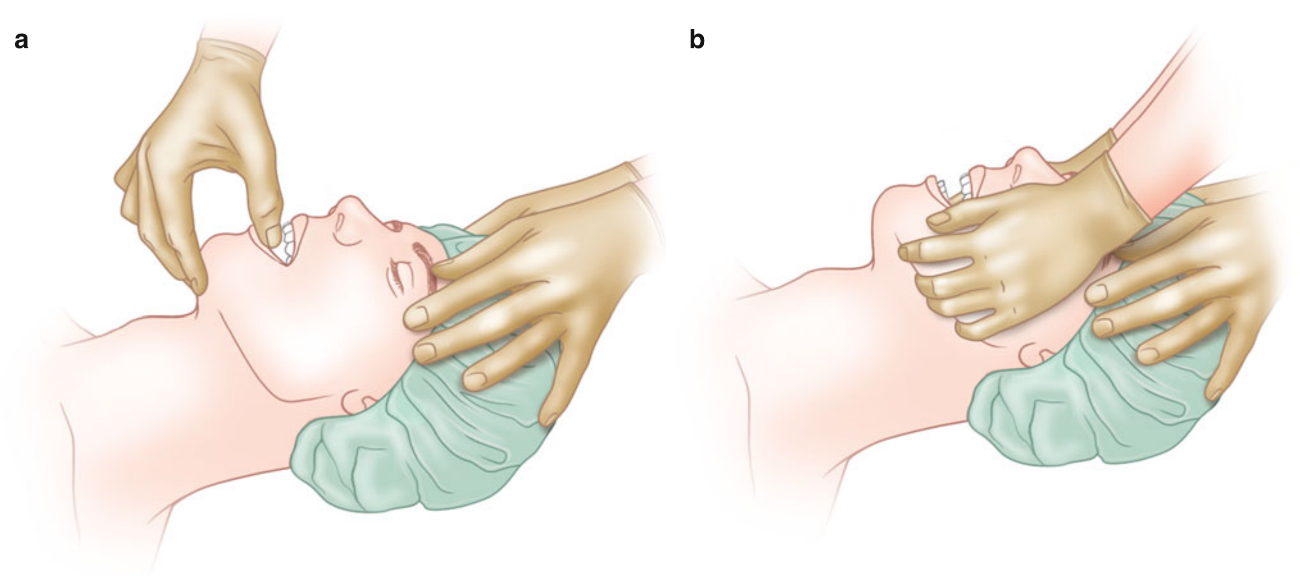


Fig. 1.16 In trauma, both the chin lift (**a**) and jaw thrust (**b**) are performed with the head supported in the neutral position (to protect the cervical spine). The "sniffing position" is therefore contraindicated

Fig. 1.17 Use of a tongue suture to facilitate intubation. A large deep tongue laceration is also being rapidly closed. Bleeding from it was preventing a clear view of the vocal cords

Once reduced, it may be necessary to provide support with a mouth prop (if the patient has an intact lower jaw).

1.6.2 Airway Maintenance Devices

A number of devices to maintain an airway are currently available, but the use of some of these in trauma (especially facial) is controversial. The laryngeal mask airway (LMA) has found widespread use in elective anaesthesia. Although it is cuffed to help maintain its position, in terms of airway protection it should be regarded as little more than an oropharyngeal airway. Use of the LMA requires specific training and it is not without complications (*i.e.*, it can induce vomiting and placement can produce movement of the neck). Oropharyngeal and nasopharyngeal airways are also commonly used in airway maintenance. However, nasopharyngeal tubes are generally regarded as contraindicated in the presence of midface or craniofacial trauma.

Fig. 1.18 Temporary reduction of midface fractures to control haemorrhage (**a**, **b**)

1.6.2.1 Oropharyngeal Airway Insertion

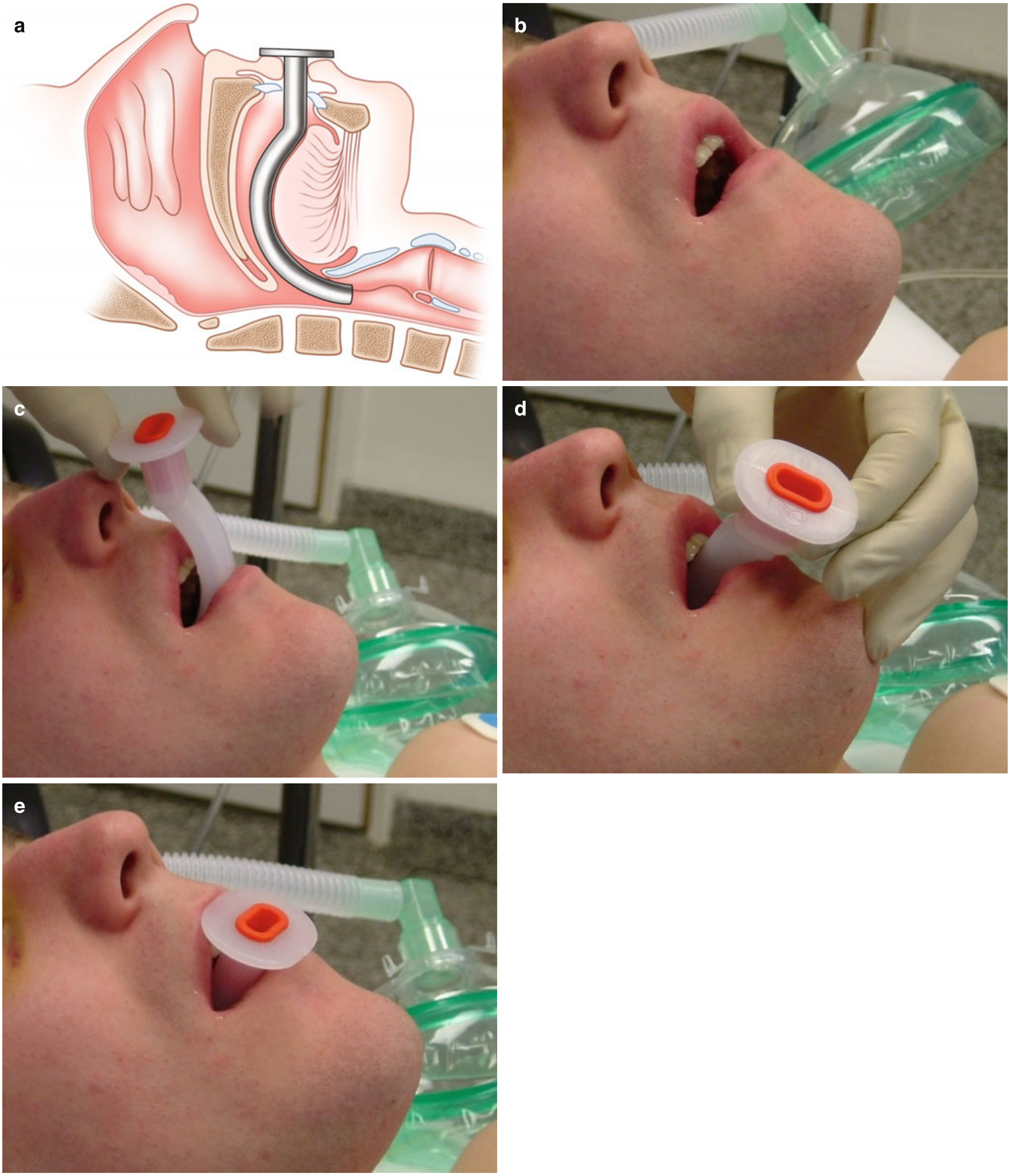


Fig. 1.19 (**a**–**e**) Insertion of an oropharyngeal airway (note inversion of tube at beginning)

1.6.2.2 Nasopharyngeal Tubes

It is important to appreciate that none of these devices provide a definitive and secure airway. Nasopharyngeal airways (as well as nasogastric/nasotracheal tubes) are generally regarded as contraindicated in midface trauma, or suspected skull base fractures, following reports of intracranial positioning. The risk of this occurring is probably lower than most people think, but nevertheless passing such semirigid tubes through the nasal cavity may still displace fractures of the cribriform plate and possibly tear the dura.

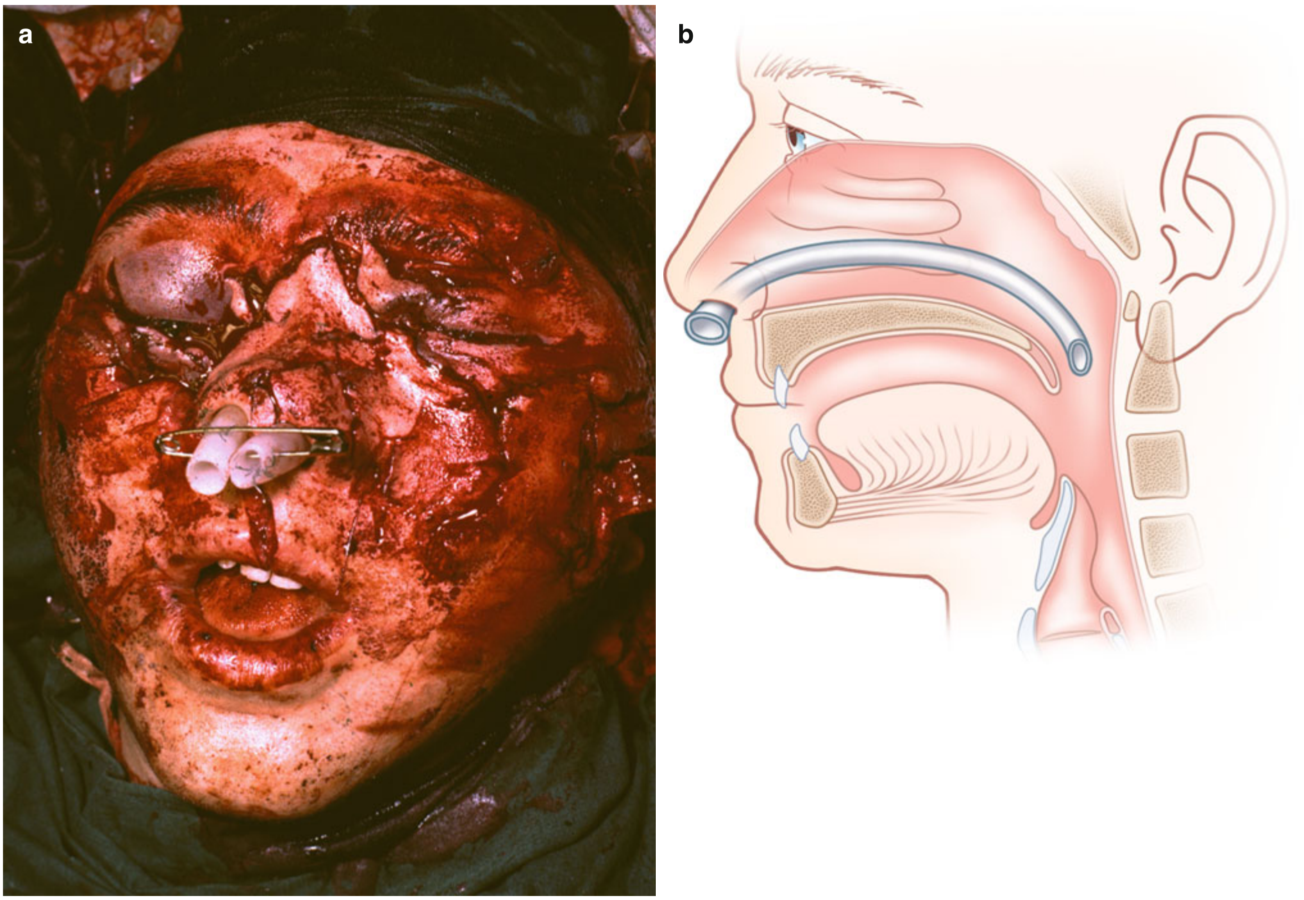


Fig. 1.20 Nasopharyngeal tubes (**a**, **b**) are generally regarded as contraindicated in midface or craniofacial trauma. In this case, the patient was alert and communicative and the risk of misplacement was to be considered low. An oropharyngeal airway would not have been tolerated. These tubes require regular suction. They can quickly become blocked with clotted blood

1.6.3 Vomiting in the Restrained Supine Patient (Before Spinal Clearance)

Vomiting is a particularly difficult problem and one that can occur suddenly, with very little warning. It puts the airway immediately at risk, especially in patients who are immobilised on a spine board. All patients are at risk of this, but those with facial injuries are at greater risk. Factors that predispose to vomiting include a full stomach, alcohol intoxication, and brain injuries, all of which are frequently associated with facial trauma. Swallowed blood (which may initially go unrecognised in awake supine patients), also seems to be a potent stimulus to nausea and vomiting. Early warning signs may include repeated requests or attempts by the patient to sit up. These should not be simply interpreted as difficult behaviour secondary to drugs, alcohol, or brain injury.

Difficulty arises in deciding which patients are at such a high risk of vomiting and pulmonary aspiration, that they should be urgently anaesthetised and intubated to secure the airway. This decision is even more critical if transfer outside the resuscitation room is necessary. However, anaesthesia and intubation are not without risks and this will also limit any further clinical assessment (especially the abdomen, central nervous system, and muscle compartments). Most patients with minor or moderate facial injuries do not vomit, and a pressing indication to immediately secure the airway is usually not present. Senior anaesthetic assistance is therefore usually advisable to evaluate the risks and benefits of intubation.

If vomiting does occur, a clear and coordinated plan of action is necessary (*see* Table 1.11).

Table 1.11 Management of vomiting in the supine patient

If the patient is securely strapped to the spine board, lowering the head of the trolley approximately 6–12 in and applying high-flow suction is probably the safest way to clear the airway and maintain spinal protection. This is a procedure that any single-handed clinician can do safely.
Tilting the board laterally is awkward and puts the spine at risk if the straps are loose or have already been released. Spinal movement still occurs as the patient slides across the board. This also requires several people and cannot be done if you are on your own.
Log-rolling a patient is a coordinated technique requiring at least four individuals to perform safely. When warning signs are recognised and time allows, this may be possible. However, vomiting can occur at any time and often after the primary survey, when the trauma team has dispersed.

Anticipate vomiting and have a clear and agreed plan of action if it occurs. Different members of the trauma team may attempt different things. This will result in confusion and delay.

Tilting the head of the trolley down approximately 6–12 in and applying high flow suction is probably the safest way to manage vomiting and maintain spinal protection. It can also be safely done by one person.

Patients who are still supine and in head-blocks should have an experienced nurse escort with them at all times until the cervical spine is "cleared" and the blocks removed.

1.6.4 Definitive Airways

A definitive airway is defined as a *cuffed tube in the trachea*. This may be required if there is doubt about the patient's ability to protect their own airway. If significant oropharyngeal swelling is anticipated, it is often better to secure the airway early before it becomes too difficult to do so. This requires experienced clinical judgment. The choice of definitive airway includes orotracheal intubation, nasotracheal intubation, and surgical cricothyroidotomy. All are relatively safe in experienced hands, even in the presence of an unstable cervical spine injury.

Orotracheal intubation with inline cervical immobilisation is usually the technique of choice in the majority of cases. Although radiographic studies have demonstrated that some movement of the cervical spine still occurs, inline cervical immobilisation has been shown to be clinically effective, even in the presence of an unstable cervical spine injury (*see* Fig. 1.21).

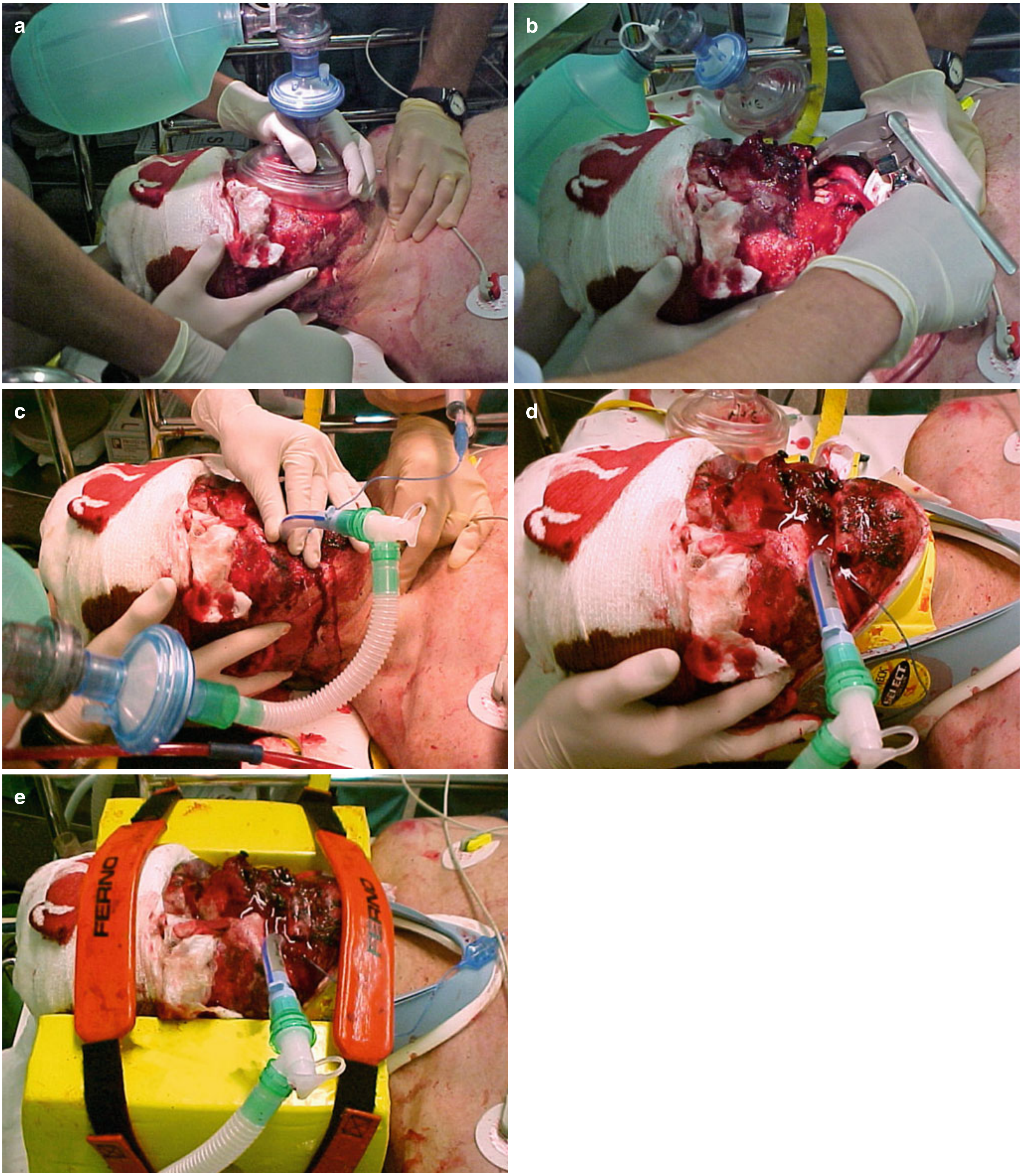


Fig. 1.21 (**a**–**e**) Urgent anaesthesia and orotracheal intubation in facial trauma is difficult but not impossible. It requires considerable expertise and a lot of assistance. The head must be supported throughout to protect the cervical spine

1.6.4.1 Orotracheal Intubation

Surprisingly, intubation can sometimes be easier than anticipated in extensive fractures. This is because the mobile facial bones can be gently displaced by the laryngoscope, providing an adequate view of the vocal cords. Difficulty in visualising the cords is more likely when there is ongoing bleeding and swelling of the pharynx and base of the tongue. Despite this observation, it is nevertheless prudent to be prepared to carry out an immediate surgical airway, just in case airway control is not possible.

In the absence of midface or craniofacial fractures, alternative techniques include blind nasotracheal intubation or fiberoptic assisted oro- and nasotracheal intubation. Together with surgical airways, these techniques have all been shown to result in minimal movement of the injured cervical spine. However, they all require extensive training. Awake fiberoptic intubation, although useful in spinal injuries, is not without risks, particularly if required urgently. Fiberoptic visualisation can often be obscured by bleeding. Nasotracheal intubation is generally regarded as potentially dangerous in the presence of anterior cranial base fractures, although this assumption has been challenged in the literature. “Retrograde” intubation has also been described and shown to minimise cervical spine manipulation, but its use is not well established in the trauma setting. Ultimately the final choice of technique will be made by the anaesthetist. As surgeons we should be prepared to secure a surgical airway if necessary.

1.6.5 Emergency Surgical Airways

Surgical airways are occasionally required when it is not possible to safely secure the airway by any other means. In an emergency situation, these include needle cricothyroidotomy and surgical cricothyroidotomy (also known as cricothyrotomy).

1.6.5.1 Surgical Cricothyroidotomy

Surgical cricothyroidotomy is now advocated by the American College of Surgeons (ACS) Committee on Trauma, as an appropriate alternative for emergency airway control, if endotracheal intubation is not possible (*see* Fig. 1.22). The key factor in this technique is identification of the cricothyroid membrane. In adults this averages approximately 1 cm vertically and 3 cm horizontally. A slightly smaller endotracheal tube than usual is therefore required (cuffed, size 4 or 5). Several surgical techniques are reported in the literature.

> Tracheostomy is generally regarded as obsolete in the emergency trauma setting. It is a relatively time-consuming procedure and is potentially unsafe. The trachea is deeper than the cricothyroid membrane and bleeding is more likely if the thyroid isthmus is encountered. For the inexperienced surgeon, a surgical cricothyroidotomy is much quicker and safer to perform. The need to convert cricothyroidotomy to a tracheostomy at a later date has also been questioned.

Many authorities argue that the only absolute contraindication to surgical cricothyroidotomy is in children, although the exact age above which it can be safely performed is not clearly defined. Infants and children under 12 years have a smaller cricothyroid membrane and a different-shaped larynx compared with adults. The Paediatric Advanced Life Support (PALS) course defines the paediatric airway as age 1–8 years, although some specialists argue it should be up to age 12. In children under 12, needle cricothyrotomy may be preferable, although the advice of an appropriate paediatric airway specialist should be sought if time allows.

Some surgeons also prefer to replace a cricothyroidotomy with a tracheostomy within 24 h. This is because a long-term cricothyroidotomy stoma has been reported to be associated with a higher risk of glottic and subglottic stenosis than tracheostomies. However, the literature on this is controversial. Other reports conclude this is not the case.

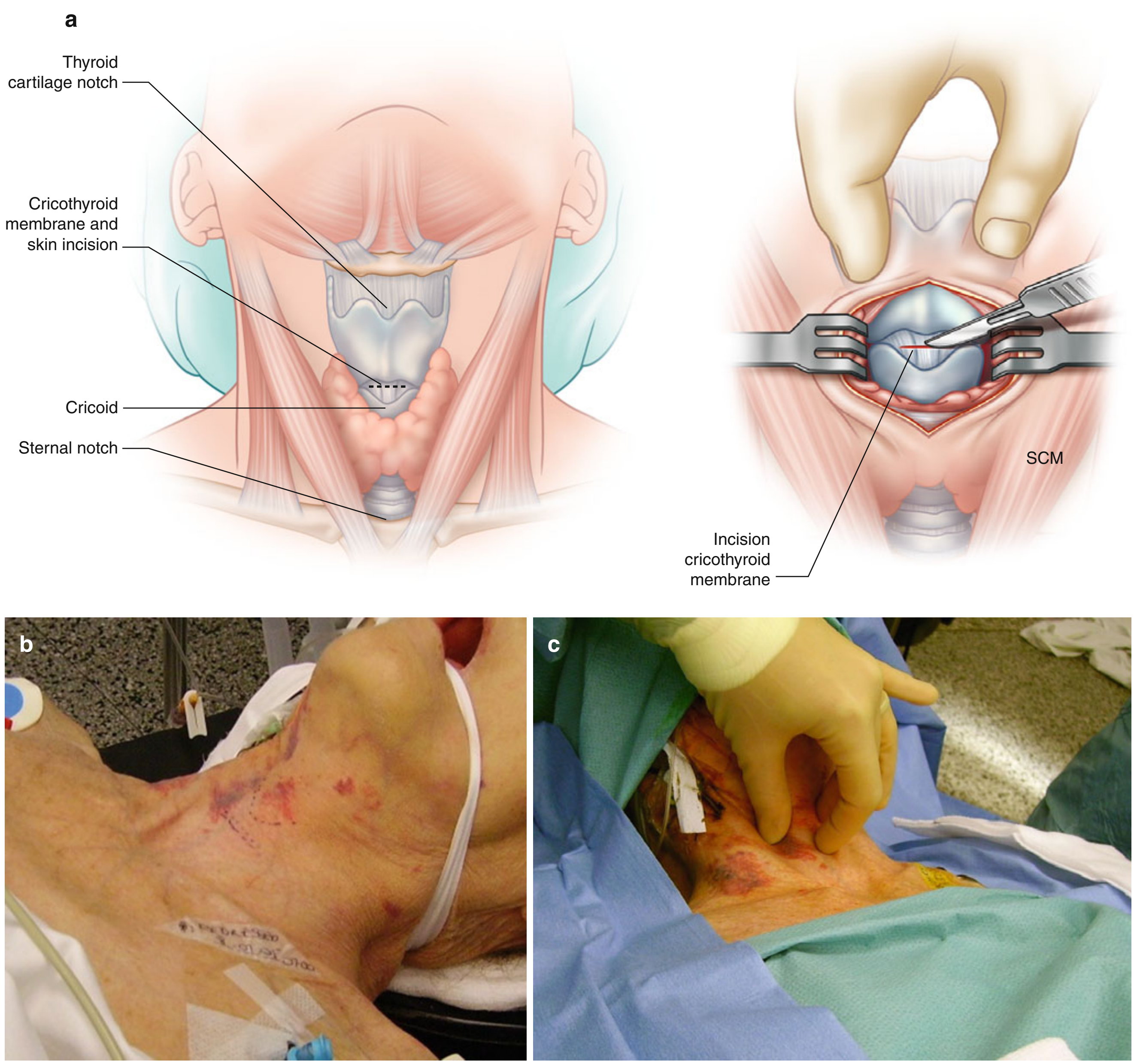


Fig. 1.22 Surgical cricothyroidotomy. (**a**) The cricothyroid (C-T) membrane passes between the thyroid cartilage (Adam's apple) and cricoid ring. It is usually covered by a relatively thin layer of skin and subcutaneous tissues, making access to it relatively simple. (**b**) Case 1. The patient is positioned supine and the thyroid cartilage is gently grasped from above (**c**). Some surgeons describe its contour like the keel of a boat, with the membrane at the lower end. The C-T membrane is then palpated by the index finger (**d**, **e**). It has a slightly "bouncy" feel to it. (**f**, **g**) Initial skin incision. (**h**, **i**) The skin and subcutaneous tissues are bluntly dissected to expose the C-T membrane immediately below. (**j**, **k**) The membrane is then incised. Some surgeons insert the handle of the scalpel blade and gently twist it to open up the hole. (**l**, **m**) The incised membrane is opened with either the handle of the scalpel or a spreader. (**n**, **o**) The tracheostomy tube (or endotracheal tube) is then placed under direct visualisation. (**p**, **q**) Case 2. In experienced hands this procedure can be done in 10–20 s. It is very rapid and provides a safe secure (but relatively small diameter) airway

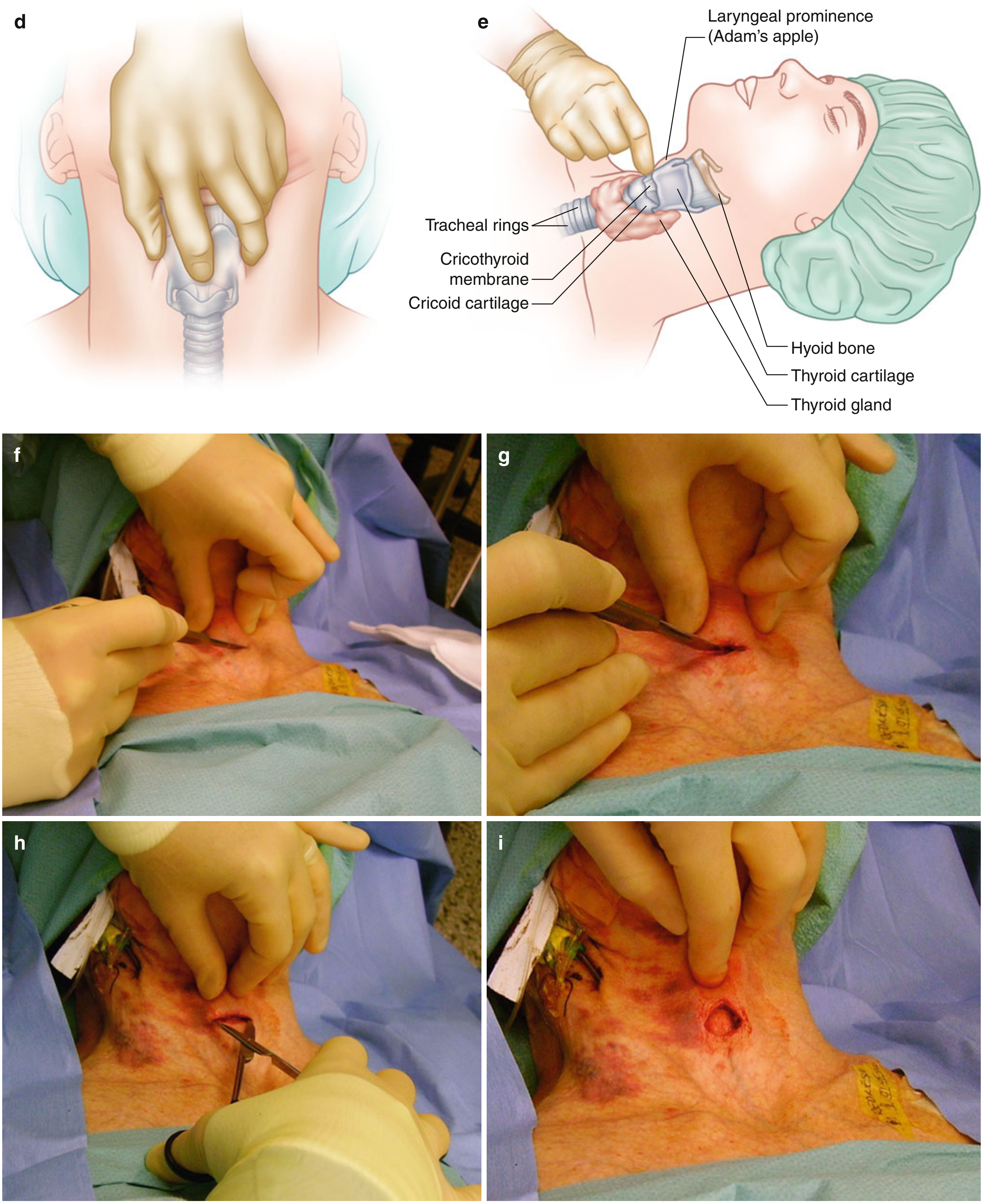
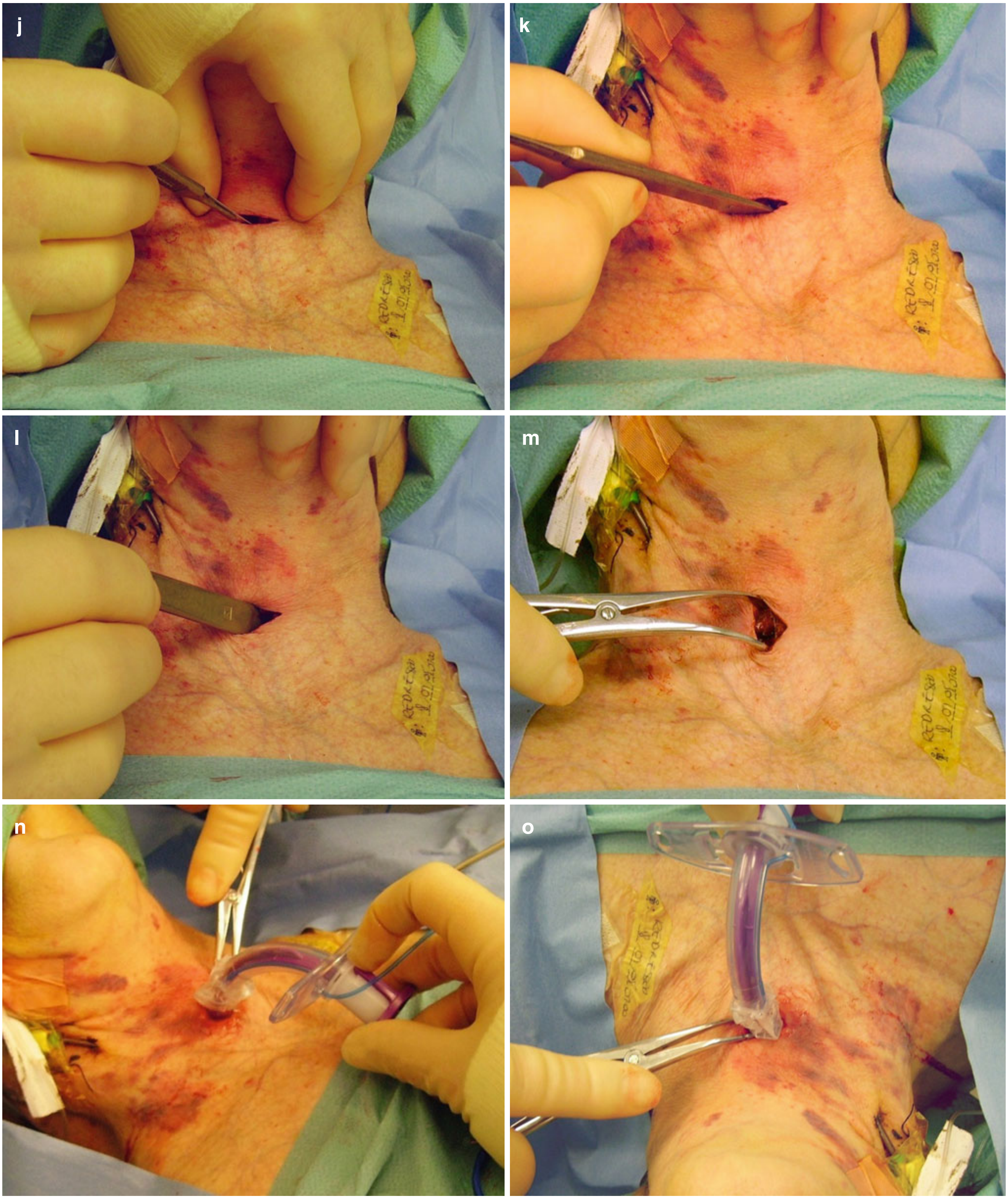


Fig. 1.22 (continued)



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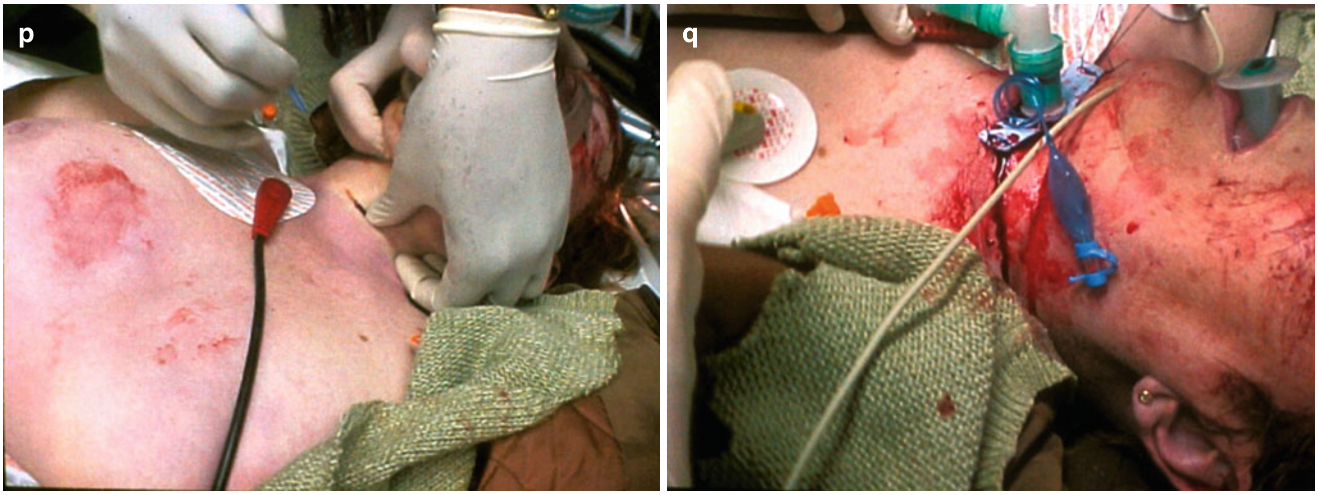

Fig. 1.22 (continued)

1.6.5.2 Needle Cricothyroidotomy

> The aim of needle cricothyroidotomy is to place a cannula into the upper airway through the C-T membrane. Although this facilitates oxygenation, the patient cannot be ventilated. CO_2 will therefore quickly rise.

Needle cricothyroidotomy is a procedure that is sometimes used to oxygenate the patient while preparing for a surgical cricothyroidotomy. However, it is not a secure or definitive procedure. Its main role is to rapidly oxygenate those patients *in extremis* while a definitive airway is being prepared. A cannula is introduced into the lumen of the trachea through the cricothyroid (C-T) membrane. Once this has been confirmed to be in the correct position, 15 L/min of O_2 is delivered by a Y connector or three-way tap device. The usual recommendation is 1 s inspiration and 4 s expiration. If there is total upper airway obstruction, the oxygen supply is reduced to 2 L/min insufflation to avoid hyperinflation. Jet inflator devices are now available to help maintain ventilation.

However, it is important to note that this procedure will only deliver 250 mL O_2 into the trachea during each inspiration, some of which will pass up into the upper airway rather than down into the lungs. Because the patient is not being ventilated, CO_2 control cannot be maintained. A definitive airway should therefore be placed as soon as possible so that the patient can be ventilated (*see* Figs. 1.23 and 1.24).

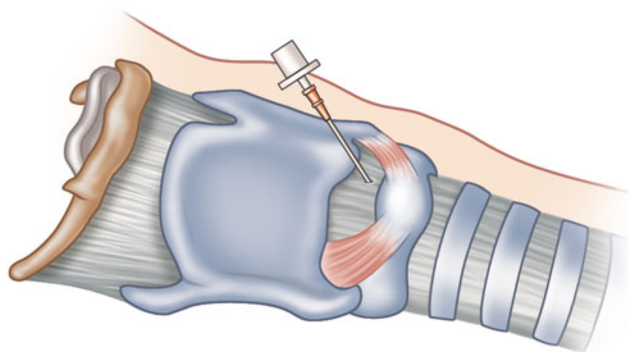

Fig. 1.23 Needle cricothyroidectomy. The aim of needle cricothyroidotomy is to place a cannula into the upper airway through the C-T membrane. Although this facilitates oxygenation, the patient cannot be ventilated. CO_2 will therefore quickly rise

> It is essential to check the cannula position carefully before attaching the device. If the cannula tip lies outside the tracheal lumen, the high pressures generated during attempted oxygenation will cause massive surgical emphysema in the tissues. This could make subsequent airway control impossible.

Fig. 1.24 Needle cricothyroidotomy in an awake patient. (**a**) Local anaesthesia is infiltrated first. (**b**, **c**) Placement of the cannula. (**d**, **e**) The cannula is secured and "jet insufflation" commenced

Table 1.12 Complications of emergency surgical airways

Surgical cricothyroidotomy
Aspiration
Subglottic stenosis
Haemorrhage/haematoma
Mediastinal emphysema
Laryngeal stenosis
Oesophageal/tracheal laceration
Creation of false passage into the tissue
Vocal cord injury
Needle cricothyroidotomy
Inadequate ventilation/hypoxia
Oesophageal laceration
Subcutaneous emphysema
Hypercarbia
Pulmonary aspiration (blood)
Posterior tracheal wall perforation
Thyroid perforation
Percutaneous transtracheal ventilation
Pulmonary rupture
Pneumothorax/tension pneumothorax

1.7 Breathing

> If any teeth or dentures have been lost and the whereabouts unknown, a chest radiograph (CXR) *and soft tissue views of the neck* should be taken to exclude their presence both in the pharynx and lower airway. A CXR by itself is inadequate.

In the context of facial injuries, breathing problems may occur following aspiration of teeth, dentures, vomit, and other foreign materials. If teeth or dentures have been lost and the whereabouts unknown, a CXR *and soft tissue views of the neck* should be taken to exclude their presence both in the pharynx and lower airway. A CXR by itself is inadequate, as highlighted by the examples shown. Occasionally, CT scanning or fiberoptic endoscopy may be necessary (*see* Figs. 1.25, 1.26, 1.27 and 1.28).

Unfortunately, acrylic (from which dentures are made) is not obvious on a radiograph and a careful search is necessary. Ideally all foreign bodies need to be removed.

If the patient has sustained multiple injuries, then other life-threatening ventilation or "B" problems should also be examined for. These fall beyond the scope of this book, but are well described elsewhere in the trauma literature.

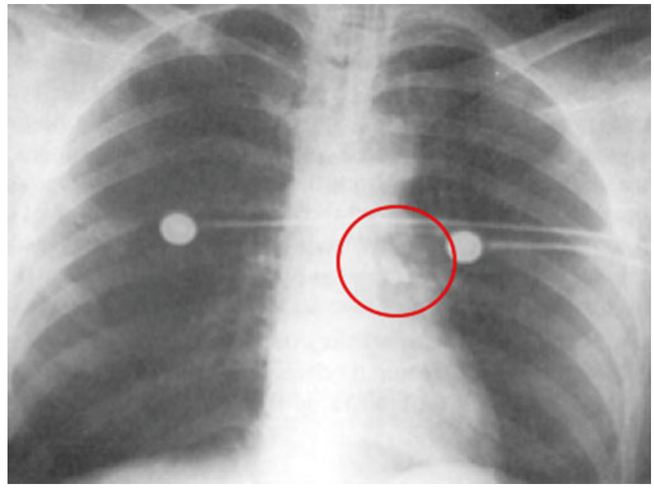

Fig. 1.25 Tooth in lung. These can easily be missed on a plain film. With the newer adjustable digital images this is less likely

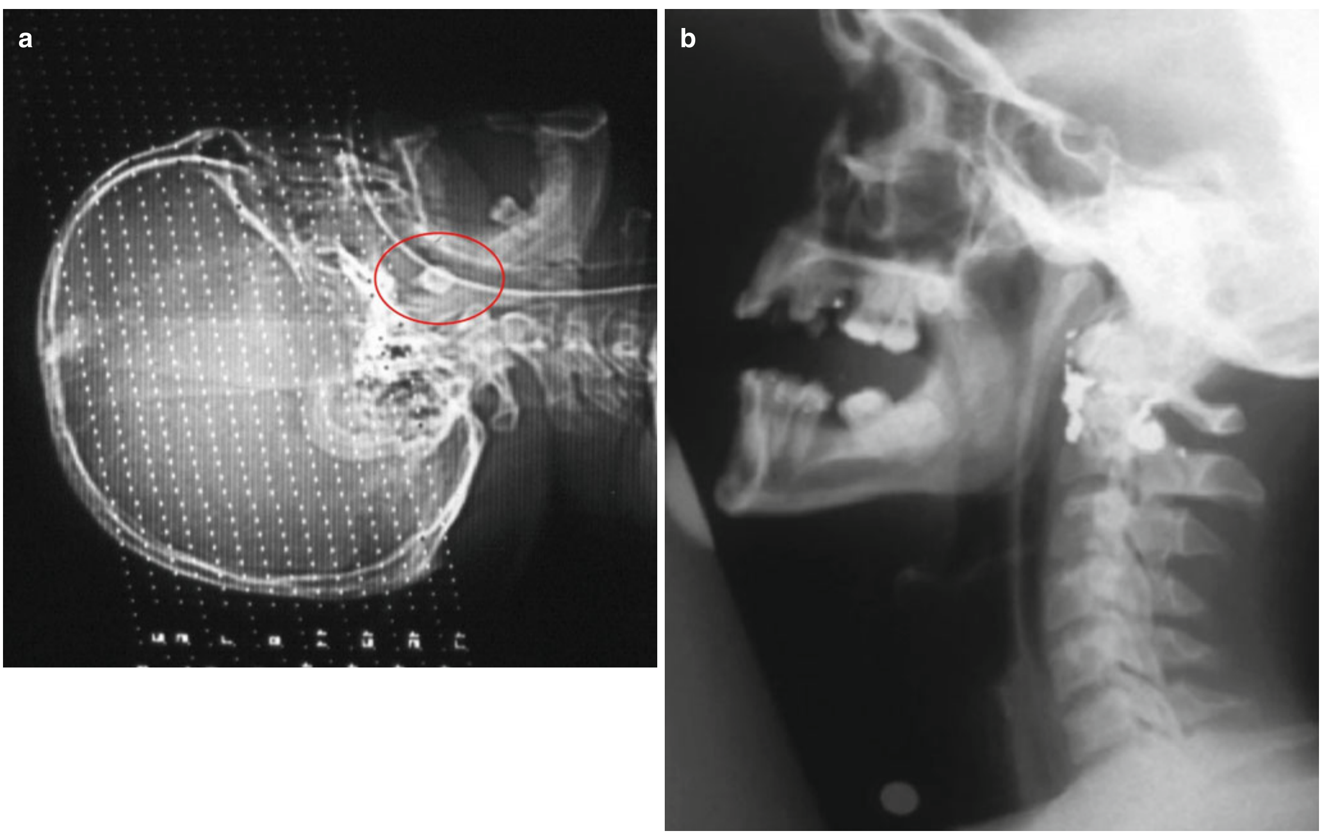

Fig. 1.26 Foreign bodies in the upper airway (**a**, **b**). Often there is a history of loss of consciousness, but the absence of this is no safeguard

Fig. 1.27 (**a**–**c**) Further examples of teeth in the upper airway. A chest radiograph alone is inadequate

Fig. 1.28 Teeth following endoscopic retrieval

1.8 Circulation

1.8.1 Initial Measures

Advanced Trauma Life Support™ teaches that "Any cold and tachycardic patient should be considered to be in hypovolaemic shock until proven otherwise." Although facial injuries are an uncommon cause of hypovolaemia, clinically significant haemorrhage has been reported to occur in approximately 10 % of "panfacial" fractures. Unfortunately, bleeding may not always be immediately apparent. It can also be difficult to control due to the extensive collateral blood supply to the face. External blood loss from the scalp, face, and neck is usually more obvious and can be profuse (*see* Fig. 1.29). In children especially this can quickly result in hypovolaemia

Active bleeding from external wounds, such as the scalp, can simply be controlled with pressure or any strong suture to hand. At this stage, the aim is to simply stop the bleeding. A continuous suture is both quick and effective in haemostasis. In the scalp, full-thickness bites are required to ensure the vessels are included in the layer. This is not a definitive closure, but simply an adjunct to "C"—control of haemorrhage.

When significant bleeding is from the depths of a puncture wound (usually in the root of the neck), placing the tip of a urinary catheter into the wound and gently inflating the balloon has been reported to be an effective measure. This technique has been reported to be highly effective in the management of actively bleeding penetrating wounds that do not respond to direct pressure. Care is required not to damage adjacent deeper structures.

The presence of active bleeding from fractures and soft tissue injuries should always be considered in all facial fractures, even the "minor" ones. On occasion what appears to be a simple broken nose can be deceptive and continue to bleed, unrecognized in the supine patient. Remember, any displaced fracture has the potential to bleed. Usually this is not torrential haemorrhage, but rather a constant trickle which, because it is swallowed, is not immediately apparent. Subsequent reassessments of the airway should therefore include a look for fresh blood in the pharynx and active bleeding from any oral wounds.

With more extensive injuries, blood loss can quickly become significant. In these patients, bleeding occurs from multiple sites along the fractures and from torn soft tissues, rather than from a named vessel. This makes control difficult. Significant concealed bleeding may occur in the supine patient, and should therefore be considered in cases of persisting shock. These patients are also likely to develop significant soft tissue swelling and the airway may need to be secured early. Once intubated, blood loss then becomes more apparent, as blood is no longer swallowed and overspills from the mouth and nose.

In addition to regular clinical examination, arterial blood gases are particularly useful in the early detection of haemorrhagic shock. Lactic acidosis is a good indication of tissue hypoperfusion and many blood-gas machines now measure lactate in addition to base deficit.

> If the patient is not actively bleeding, check the blood pressure. If this is low, haemostasis may only be temporary. Once the systemic blood pressure has been restored, the patient may then start to rebleed. Anticipate this and consider haemostatic techniques before bleeding occurs (*see* Fig. 1.30).

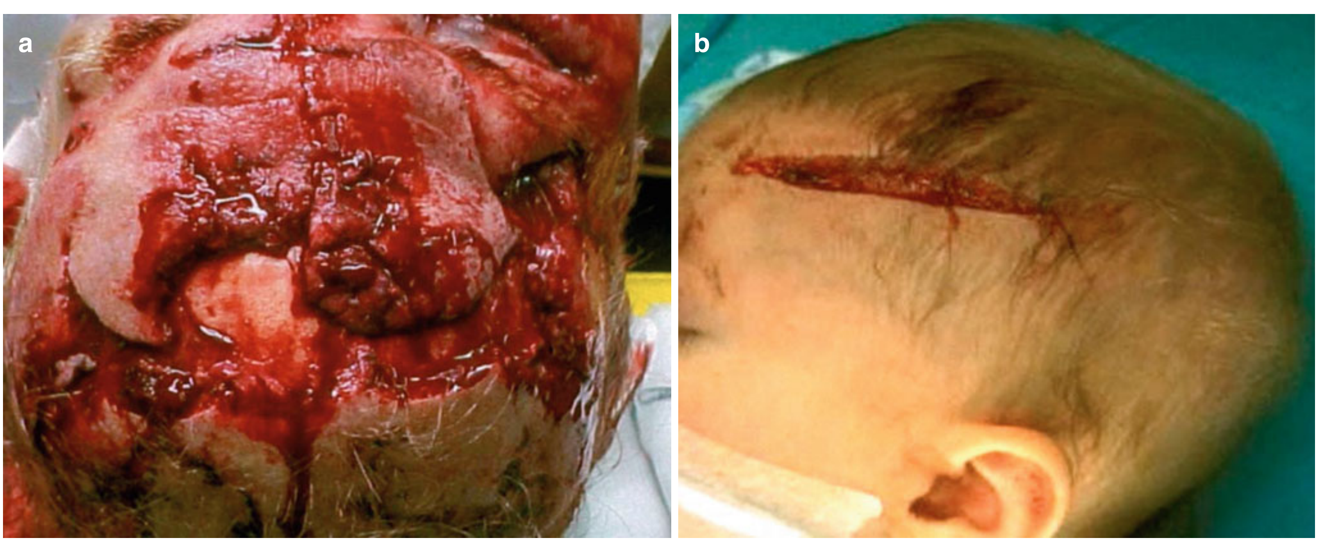

Fig. 1.29 Bleeding from the scalp (**a**) can quickly result in haemorrhagic shock, especially in children (**b**)

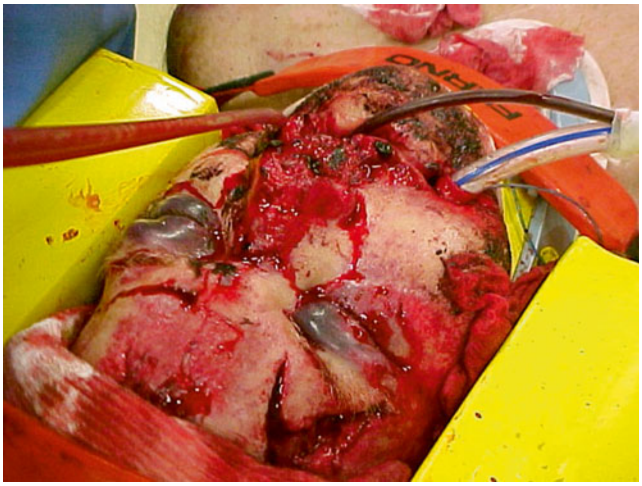

Fig. 1.30 This patient initially presented with hypovolaemic shock, but only minor facial bleeding. There were no significant injuries below the clavicles. It was only when his systolic pressure was restored that profuse bleeding from the face became apparent. This should have been anticipated in view of the extensive fractures

Table 1.13 Fluid therapy in the multiply injured patient

Guidelines continue to evolve. Current evidence suggests that vigorous fluid administration in the presence of uncontrolled bleeding may be harmful. The term "uncontrolled" haemorrhage generally refers to significant bleeding that requires immediate surgical or radiologic intervention to control. In practical terms, this usually refers to external wounds with obvious bleeding, massive haemothorax, ongoing mediastinal bleeding, and bleeding into the abdomen and pelvis.
Instead of 1–2 L as an initial fluid bolus, smaller volumes (250 mL in adults) with frequent reassessment have been recommended. The aim is to maintain the systolic blood pressure high enough to perfuse the brain (*i.e.*, at 80 mmHg or a palpable radial pulse), until any significant bleeding has been controlled. Then more aggressive fluid resuscitation can begin. If the systolic pressure is normalised *before* bleeding is controlled, the increase in pressure may dislodge any newly formed clots and precipitate further bleeding. This is sometimes referred to as the "pop the clot" phenomenon.
However, this approach is complicated in the presence of associated brain injury, where hypotension is harmful and a higher systolic pressure may be required.
Debate also continues regarding the relative merits of crystalloid and colloid solutions. Several guidelines now suggest initial fluids should be crystalloid.

1.8.2 Management of Major Facial Haemorrhage

Early control of blood loss is essential in all trauma patients. The patient's own blood at their normal body temperature is considerably better than any fluids that can be given. Pressure should be applied to any actively bleeding wounds as the patient arrives. Although "Airway" and "Breathing" precede "Circulation," it is now accepted that one should not ignore an obvious spurting wound (if the patient is not moribund or in respiratory distress). It only takes a few seconds for someone to apply pressure with some gauze.

As soon as "A" and "B" have been formerly addressed, the next priorities are to stop any further blood loss and establish wide-bore intravenous access through which fluids may be given. *How much fluid* and *what type of fluid* are currently two areas of controversy in the literature (*see* Table 1.13). "Permissive hypotension" and "damage control (limitation) surgery" are a part of this ongoing debate and these can have a major impact on the management of facial injuries.

External bleeding should initially be controlled using direct pressure, clips, or sutures. When displaced midface fractures are present, early manual reduction not only improves the airway, but helps control blood loss (even though reduction is not anatomic) (*see* Fig. 1.31).Once reduced, a mouth prop can help maintain support. In extensive injuries, early intubation should be considered, not only to protect the airway, but also to allow effective control of bleeding with packs, etc.

If anaesthesia and intubation is undertaken, manual reduction of facial fractures can then be carried out more easily. If anaesthesia and intubation are not undertaken, the patient needs to be regularly reassessed. Failure to control haemorrhage by simple measures is an indication for anaesthesia and intubation. At all times the cervical spine must be carefully immobilised (unless the neck has been cleared).

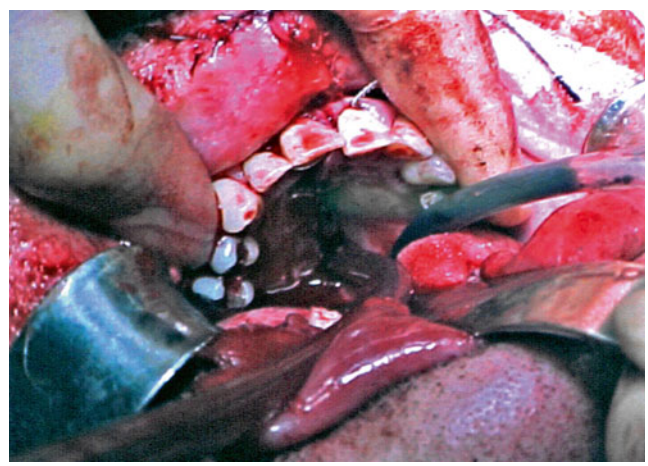

Fig. 1.31 Severe midface fractures with a split palate. There has been significant blood loss requiring immediate reduction of the fractures

If the patient's cervical spine has not been "cleared," intubation will require the hard collar to be unfastened and opened. Therefore, manual in-line immobilisation will be necessary until the collar, blocks, and straps have been replaced. Once the patient is intubated, manually reducing the fractures is much easier and bleeding can be more effectively controlled. If fracture reduction proves to be effective in controlling bleeding, maintaining this manually for a short period provides the anaesthetist time to "catch up" with fluid administration as necessary. This technique is comparable to the manual reduction of a displaced femoral or pelvic fracture in limiting haemorrhage (*see* Fig. 1.32).

Oral bleeding can be controlled with sutures or local gauze packs. Epistaxis, either in isolation or associated with midface fractures, may be controlled using a variety of specifically

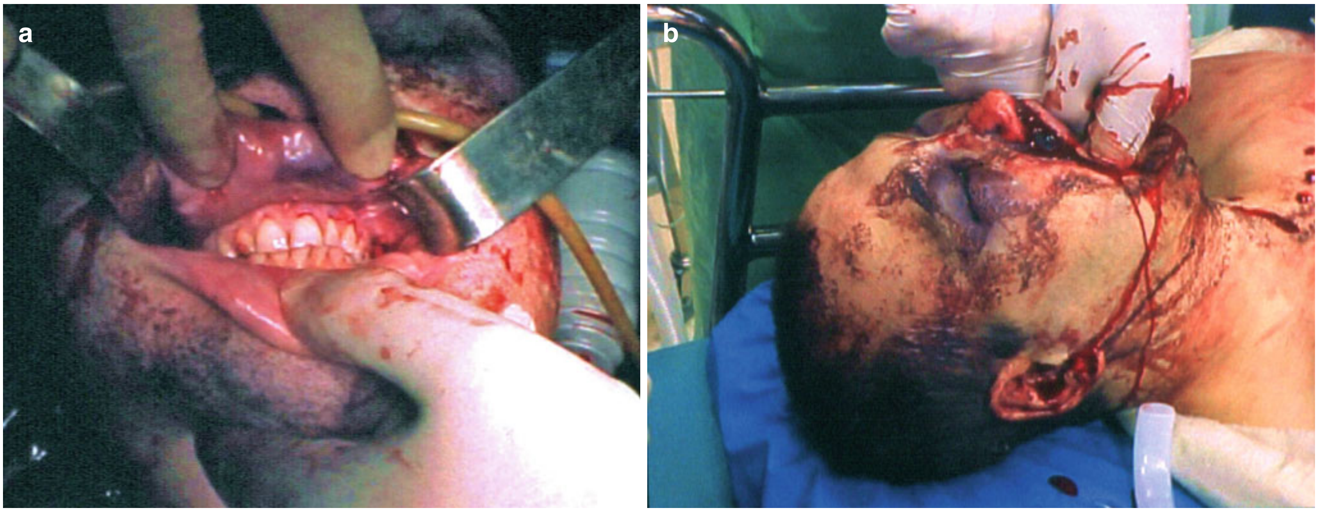

Fig. 1.32 Manual reduction of fractures is difficult, but not impossible, in awake patients. In this case (**a**, **b**), the reduction was maintained while preparing for anaesthesia and intubation (the cervical spine had been "cleared")

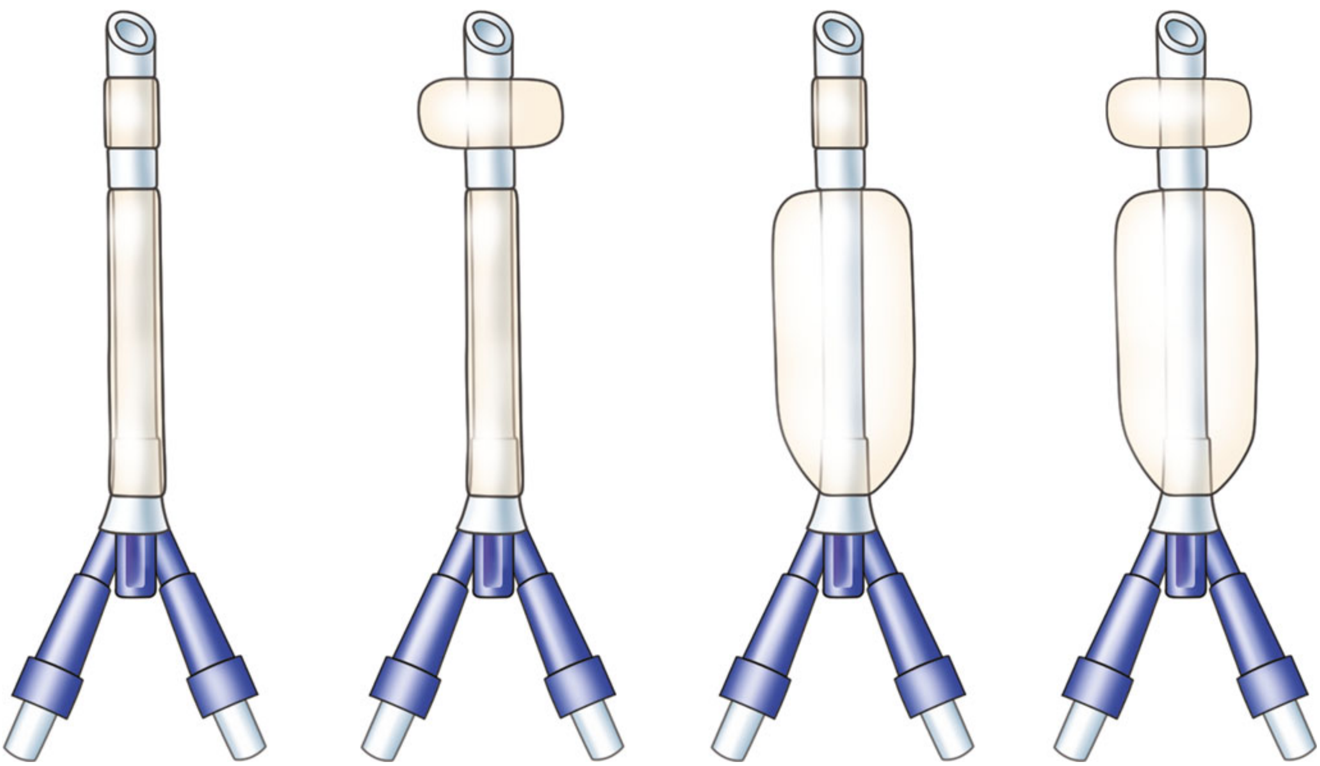

Fig. 1.33 Epistaxis balloons. These have a small balloon near the tip (to form the nasopharyngeal stop) and a larger balloon to obturate the nasal cavity. These can be inflated individually

designed nasal balloons or packs (once the midface fractures have been reduced and supported) (*see* Fig. 1.33).

If these custom devices are not available, two urinary catheters can be used. Each is passed via both nostrils into the pharynx (under direct vision), inflated with saline, and then gently withdrawn until the balloon wedges in the postnasal space. The nasal cavity can then be packed.

These techniques are commonly a source of anxiety when there are concerns about the possibility of skull base fractures and risks of intracranial intubation. However, if there is profuse haemorrhage from the midface, *something* needs to be done and the patient cannot be allowed to exsanguinate on the basis of a perceived risk. In such circumstances, safe passage of a soft catheter, under direct vision, is usually possible. Know your anatomy—soft tubes gently passed parallel to the hard palate are very unlikely to end up in the brain (*see* Figs. 1.34, 1.35, 1.36 and 1.37).

Fig. 1.34 Nasal packing using a urinary catheter (case 1). (**a**, **b**) Control of epistaxis using a urinary catheter. The hard collar is unfastened and the head supported by an assistant (**c**). The catheter is then passed backwards through one nostril, parallel to the palate and its end grasped and withdrawn out the mouth (**d**). (**e**, **f**) This is then repeated on the other side so the ends of both catheters are visible. (**g**, **h**) The catheters are then inflated with sterile water or saline. (**i**) The water-filled balloons are then gently guided back into the mouth and gently wedged in the nasopharynx. The catheters are then put on gentle traction and the hard collar replaced. (**j**) The nasopharyngeal balloons act as a stop and now enable the nose to be packed without the pack slipping into the pharynx. This technique is really only required in severe or protracted cases of bleeding when other measures have failed. Careful traction is required. If too heavy, the balloons can be pulled out through the nostrils. Also protect the nasal tip from pressure necrosis by the tube. (**k**) The nasal cavity is then packed in a layered arrangement. This is often easier said than done. The nasal cavity should now be almost water tight. If skull base or orbital fractures are suspected, this needs to be packed lightly

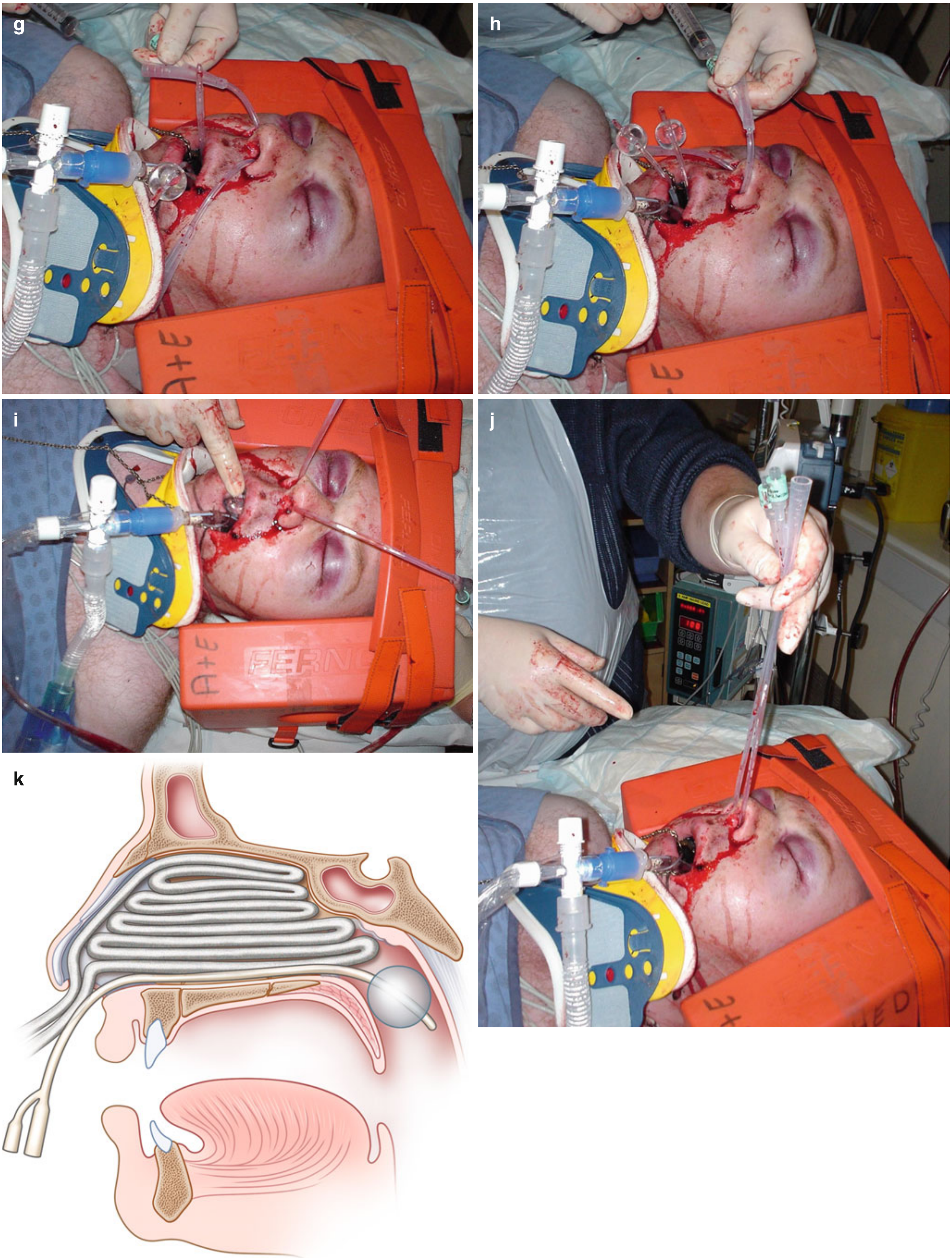

Fig. 1.34 (continued)

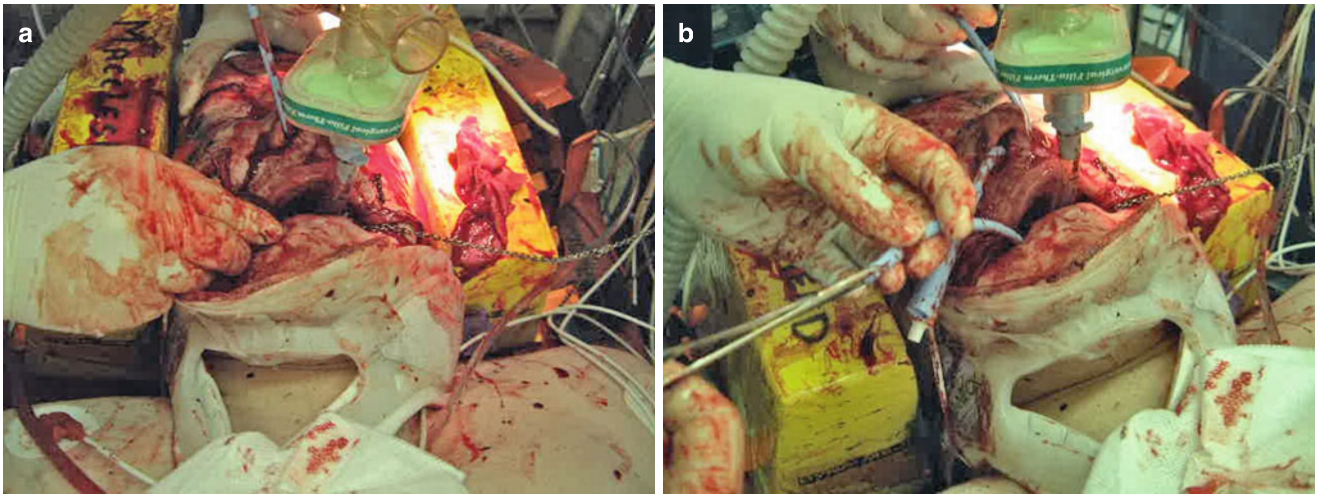

Fig. 1.35 Nasal packing using a urinary catheter (case 2). This technique requires good access to the oral cavity and pharynx (**a**). In an emergency, the hard collar will need to be unfastened and the head supported by an assistant (**b**)

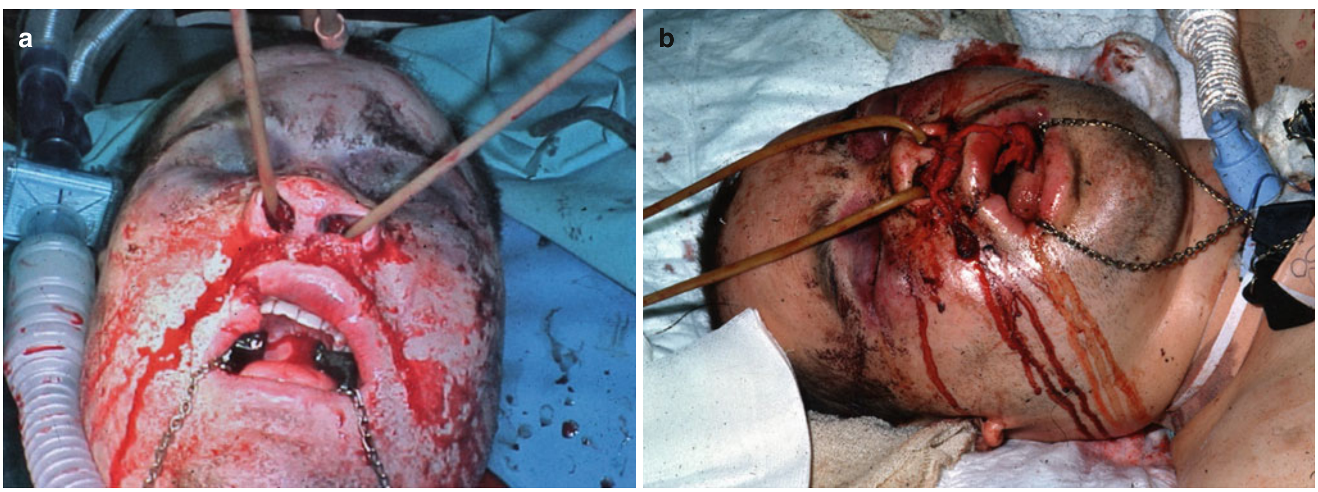

Fig. 1.36 Nasal packing using a urinary catheter (case 3). Packs are usually left in situ 24–48 h. Consider the use of antibiotics during this time (risk of toxic shock syndrome and sinusitis)

Once the catheters have been placed, gentle traction is applied to gently wedge the balloons in the nasopharynx. The nose is then packed. The balloons essentially form a posterior stop, preventing the pack from falling through the nasopharynx into the throat. Bleeding initially continues but should soon tamponade. If it does not, consider acquired coagulation defects.

Aggressive packing should be avoided, especially if anterior cranial fossa or orbital fractures are evident or suspected. Overpacking may inadvertently displace these fractures (*see* Fig. 1.38)

> Aggressive packing of the nasal cavity should be avoided, especially if anterior cranial fossa or orbital fractures are evident or suspected. Over packing may displace these fractures.

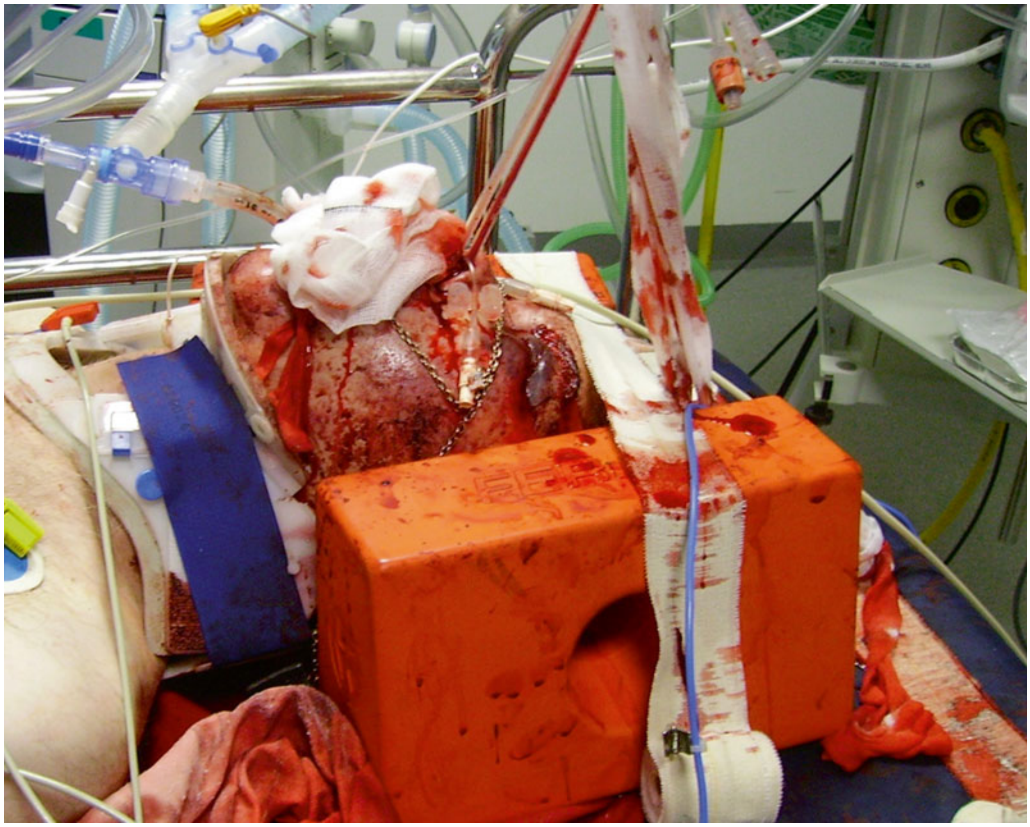

Fig. 1.37 Nasal packing using a urinary catheter (case 4). With extensive fractures, bleeding may continue from the mouth. The oral cavity can also be packed (this patient has been intubated). At this stage, consider acquired coagulation defects, if this has not already been considered

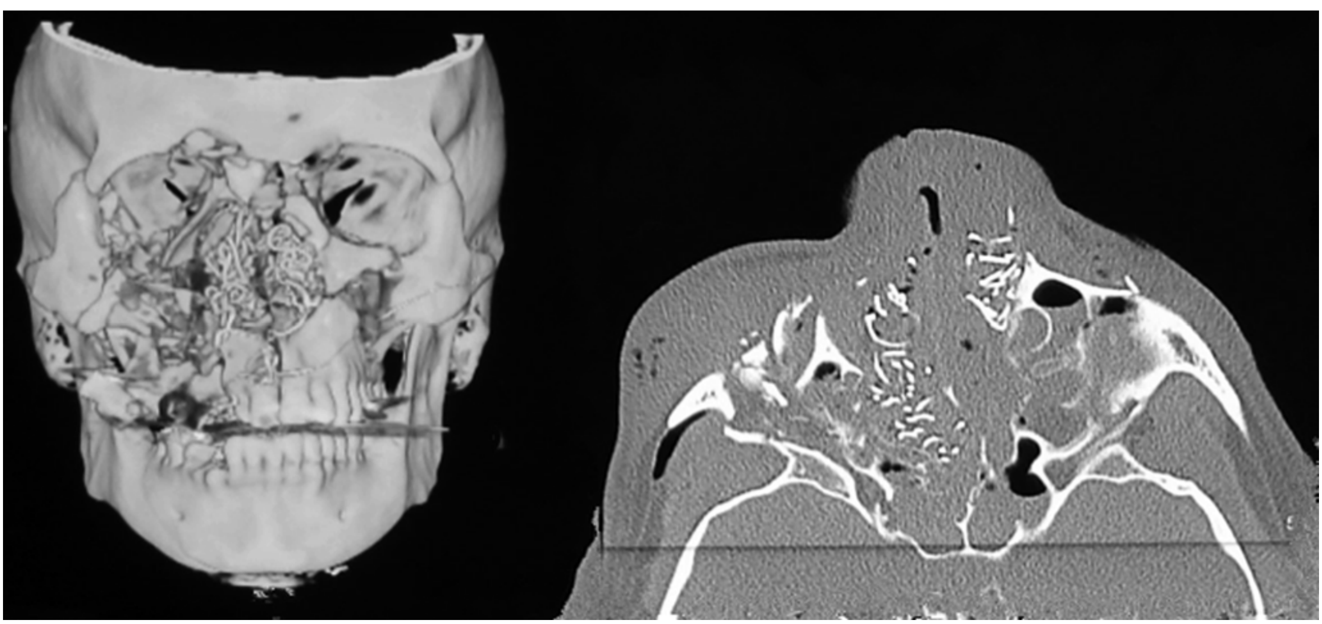

Fig. 1.38 Overpacking of the nose when the surrounding fractures are unsupported can lead to displacement. Be careful

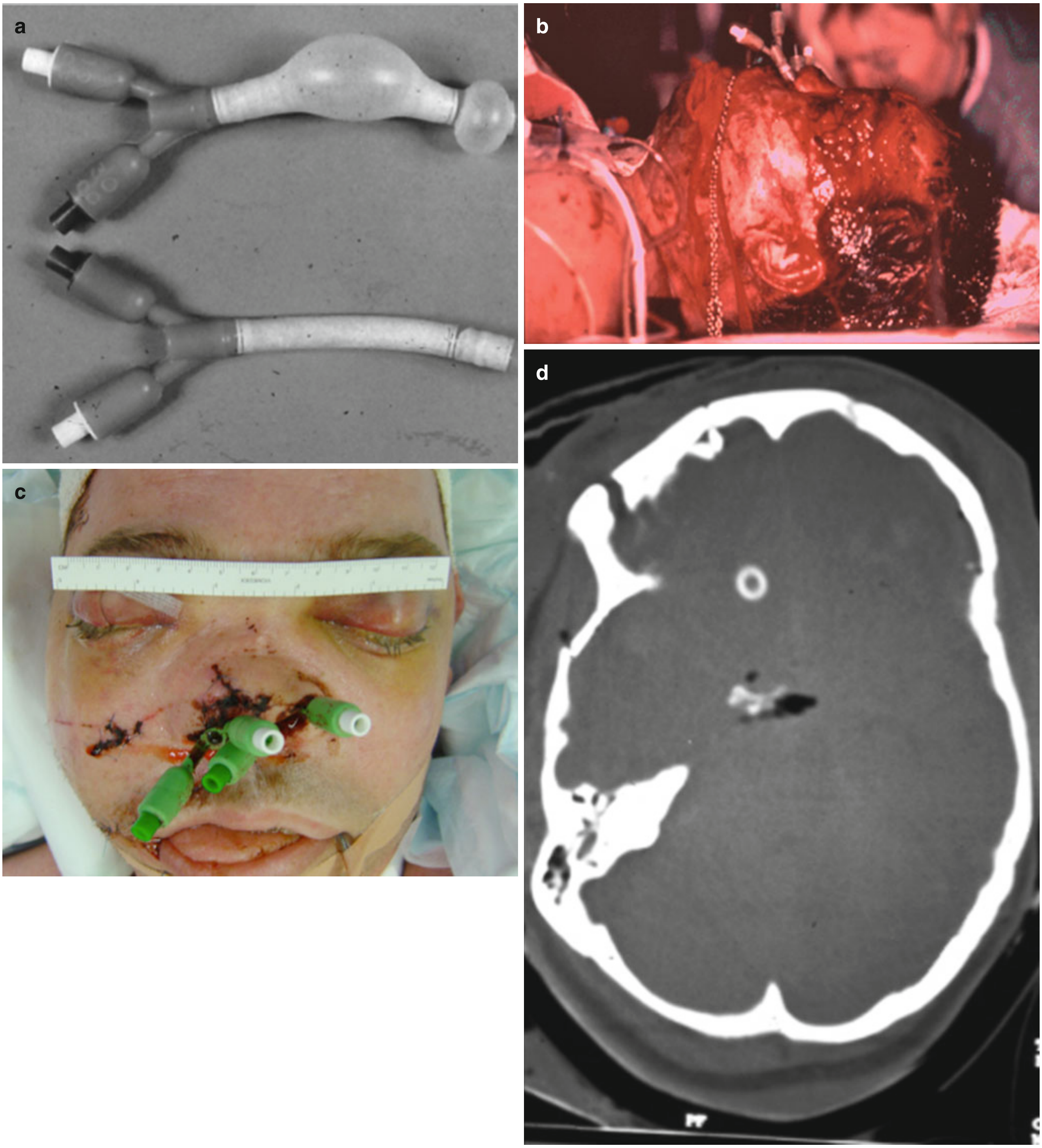

Fig. 1.39 (**a**–**c**) Epistaxis balloons. (**d**) Passing catheters, balloons and packing of the nose does carry a risk of intracranial intubation in the presence of skull base fractures, as shown here. Nevertheless, if a patient is pouring blood from the nose and mouth something clearly needs to be done. The actual risk of intracranial intubation is probably very low in experienced hands. Only pass these if you are trained to do so and know what you are doing. If not then get urgent help

Control of midface bleeding needs to be done in the correct sequence (*see* Table 1.14). These manoeuvres should only be regarded as resuscitative measures, in much the same way as wrapping a sheet around a reduced "open book" pelvic fracture reduces blood loss. The fractures are not anatomically reduced and nasal packs are not without risk. Toxic shock, sinusitis, meningitis, and brain abscess are all potential complications, although the role of antibiotic prophylaxis is not clear. Blindness has also been reported. How long packs are left in situ depends on the clinical status of the patient, but is usually around 24–48 h.

When mobile midfacial fractures are not supported, heavily packing the nasal cavity, or inflating intranasal balloons may displace the fractures further, thereby increasing blood loss. Correct sequencing is essential. Temporary stabilisation of the reduced fractures with a mouth prop is necessary before packing or inflation is attempted. If the mandible is also fractured, this needs additional support.

Table 1.14 Control of midface bleeding in the anaesthetized patient (a guide to sequencing)

Get an assistant to hold the head and protect the neck
Release the hard collar, but do not remove it (a well-fitting collar restricts mouth opening, so this is usually necessary)
Manually reduce the midface fractures to reduce bleeding
Apply suction to the nose and pharynx and look for active bleeding
1. If bleeding is controlled: Place mouth props or gauze to support the fracture and consider the need for nasal/oral packs Reapply the hard collar Check the patient's blood pressure (remember reactive bleeding)
2. If patient is still bleeding into the nasopharynx: Pass epistaxis balloons (or urinary catheters) through each nostril until the ends are visible in the oropharynx. Depending on the number of assistants, this may mean you will have to release the midface, with further bleeding. Do NOT inflate balloons while midface is unsupported. This will displace the fractures further and increase bleeding. If the midface was released, manually reduce it again. Place bite blocks or gauze to support the fracture. Then inflate the epistaxis balloons (or catheter balloons) and withdraw catheters, gently wedging balloons into nasopharynx without displacing fractures). Tie a bag of saline to ends of catheters and hang over a drip stand (for gentle traction). Gently pack the nasal cavity. Reapply hard collar.
3. If patient is still bleeding, consider coagulation disorders.
4. Check the patient's blood pressure: have they stopped bleeding because of effective control, or because they are hypotensive?

1.8.3 Surgical Control of Facial Bleeding

If haemorrhage persists despite these interventions, it is important to consider coagulation abnormalities. These may be either pre-existing (*e.g.*, haemophilia, chronic liver disease, warfarin therapy) or acquired (*e.g.*, dilutional coagulopathy). Only rarely is surgical control of facial bleeding required during the primary survey.

Facial fractures may be temporarily stabilised in various ways. These include using wires, splints, intermaxillary fixation (IMF) or occasionally plating techniques (if fracture sites are exposed). The aim of all these treatments is to rapidly reduce and stabilise the fractures. Separation of fractures and movement between them is not only painful but can result in significant bleeding and swelling. Reduction at this stage does not need to be anatomical, it just needs to be sufficient enough to arrest haemorrhage. External fixation is also very effective in providing rapid "first aid" stabilisation in the multiply injured patient, or prior to transfer. With gunshot wounds or other types of contamination, this method also provides good "medium-term" temporary fixation.

If bleeding continues despite all these measures (and there are no clotting abnormalities), further interventions include ligation of the external carotid and ethmoidal arteries via the neck and orbit, respectively. These are rarely required nowadays and are extremely difficult to undertake as emergency procedures. Due to the extensive collateral circulation of the face, ligating a single vessel is also unlikely to be successful. Add to this the urgency of haemostasis and the fact that the cervical spine may not have been "cleared" (thereby preventing turning of the head for access), it is little wonder that these techniques are now rarely undertaken and radiologic intervention is the preferred approach.

1.8.3.1 External Carotid Artery Ligation

See Figs. 1.42 and 1.43 for details of procedure.

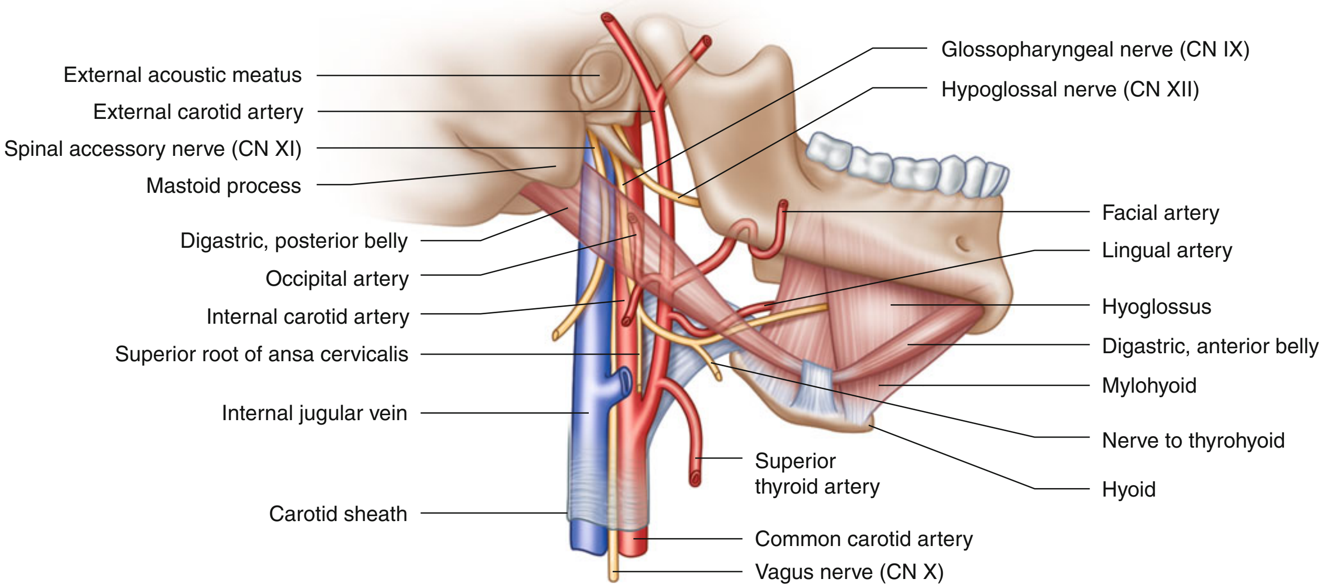

Fig. 1.40 The external carotid artery has a number of branches. This distinguishes it from the internal carotid artery

1.8.3.2 Anterior Ethmoid Artery Ligation

With the development of interventional radiology as a specialty and supraselective embolisation as a technique, ligation of the anterior ethmoid vessels is now a rarely performed procedure. Nevertheless it may occasionally be required when bleeding from the nose and central midface cannot be controlled by packing and interventional radiology facilities are not readily available.

The anterior ethmoid artery passes through the medial wall of the orbit into the upper nasal cavity supplying the central midface bilaterally. Together with the posterior ethmoid artery, these vessels' foramina are important surgical landmarks, marking the junction between the anterior cranial fossa and the orbits. The anterior ethmoid artery is approximately 20–25 mm posterior to the orbital rim. The posterior ethmoid artery is 10–20 mm deeper and the optic canal is approximately 6 mm deeper to that. Knowledge of these distances is important when dissecting along the medial orbital wall (*see* Fig. 1.44).

The anterior ethmoid artery is the larger of the two vessels. Access to it can be done either endoscopically, or through a direct transcutaneous approach. Although good access can be achieved by the direct approach, the medial canthus may become detached. Haemostasis can be achieved using diathermy or clips. Depending on the patient's clinical condition, the incision can be closed following haemostasis, or this can be deferred until later (*see* Figs. 1.45 and 1.46).

Much of the literature on the role of ethmoidal ligation relates to isolated nasal epistaxis rather than midface trauma. Because of the extensive collateral supply to the face, ligation may be necessary on both sides. Alternatively, endoscopic techniques (transantral and intranasal) have been described. These are of limited use in panfacial fractures, where there may be multiple bleeding points both in the bones and soft tissues. Endoscopic techniques are therefore best used in localised nasal injuries, resulting in uncontrollable epistaxis.

1.8.4 Supraselective Embolisation

The use of supraselective embolisation in trauma continues to evolve but has been extensively reported to be very successful, with clear advantages over surgery. It is

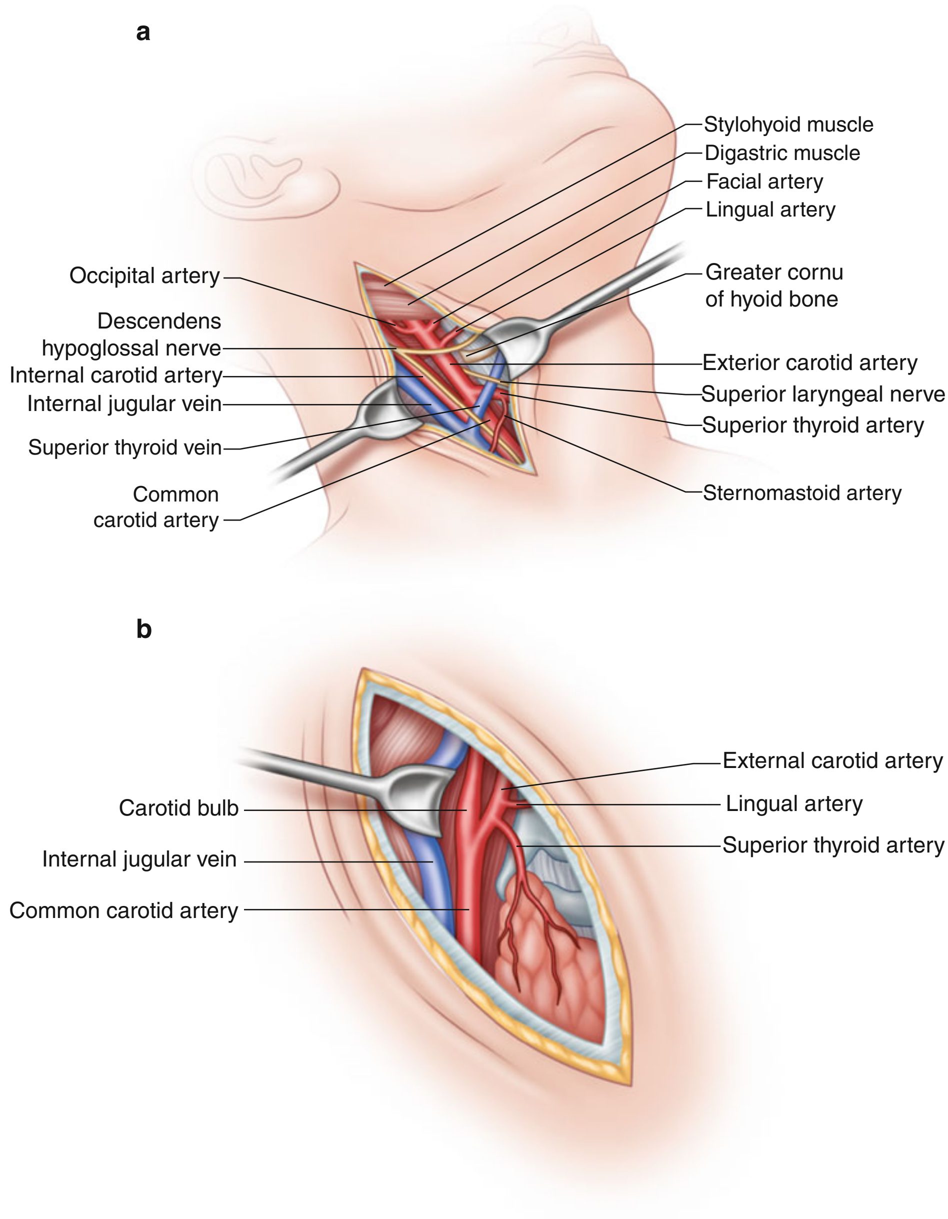

Fig. 1.41 External carotid artery ligation: illustrations of surgical exposure (**a**, **b**)

increasingly used in solid organ and extremity trauma and in bleeding secondary to pelvic fractures. It is now well documented as a successful treatment modality in penetrating injuries, blunt injuries, and intractable epistaxis. Catheter-guided angiography is used to first identify and then occlude the bleeding point(s). Embolisation involves the use of balloons, stents, coils, or a number of materials designed to stimulate clotting locally. Supraselective embolisation can be performed without the need for a general anaesthetic and in experienced hands is relatively quick. Its value therefore is seen in the unstable patient. Multiple bleeding points can be precisely identified and the technique is repeatable. However, immediate access to radiologic facilities and on-site expertise are essential. Complications include iodine sensitivity and, following extensive embolisation, end-organ ischaemia and subsequent necrosis. Stroke and blindness have also been reported (*see* Fig. 1.47).

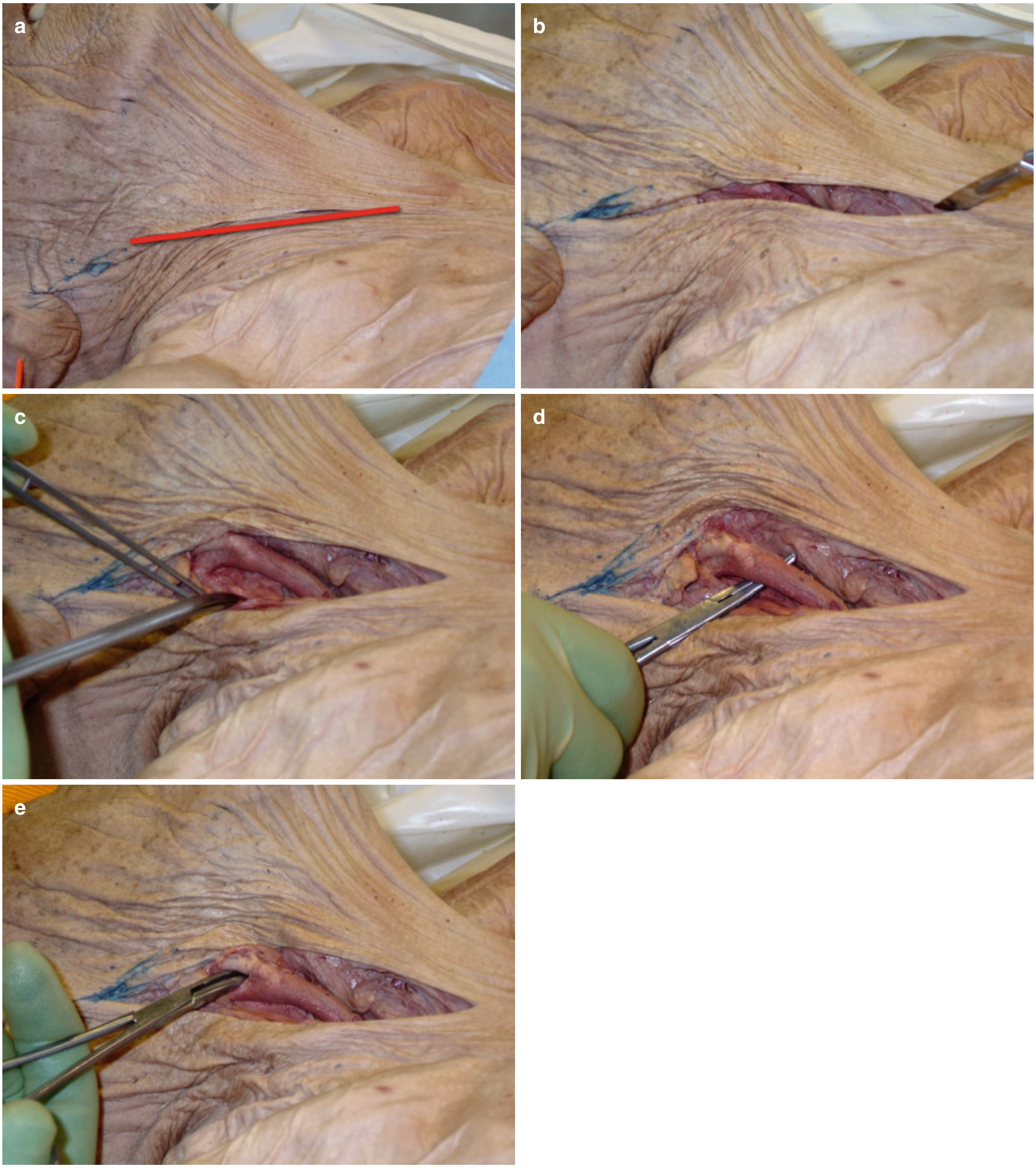

Fig. 1.42 External carotid artery ligation. (**a**, **b**) The skin is incised parallel to the anterior boarder of the sternomastoid muscle. Red line represents the incision. (**c**, **d**) The muscle is retracted and the surrounding tissues quickly (but gently) opened up. The common carotid artery is identified by palpation. (**e**, **f**) Dissection proceeds superiorly along the artery to identify the bifurcation into the internal and external carotid arteries. The external carotid artery is then identified (it gives off further branches—the superior thyroid is usually just above the bifurcation). This needs confident identification; otherwise there is a risk of ligating the internal carotid artery. (**g**, **h**) A tie is then passed around the vessel and secured. (**i**) Ligated vessel. This procedure may need to be repeated on the other side. Remember the head cannot be turned to improve access unless the neck has been cleared. Therefore this is a very difficult procedure

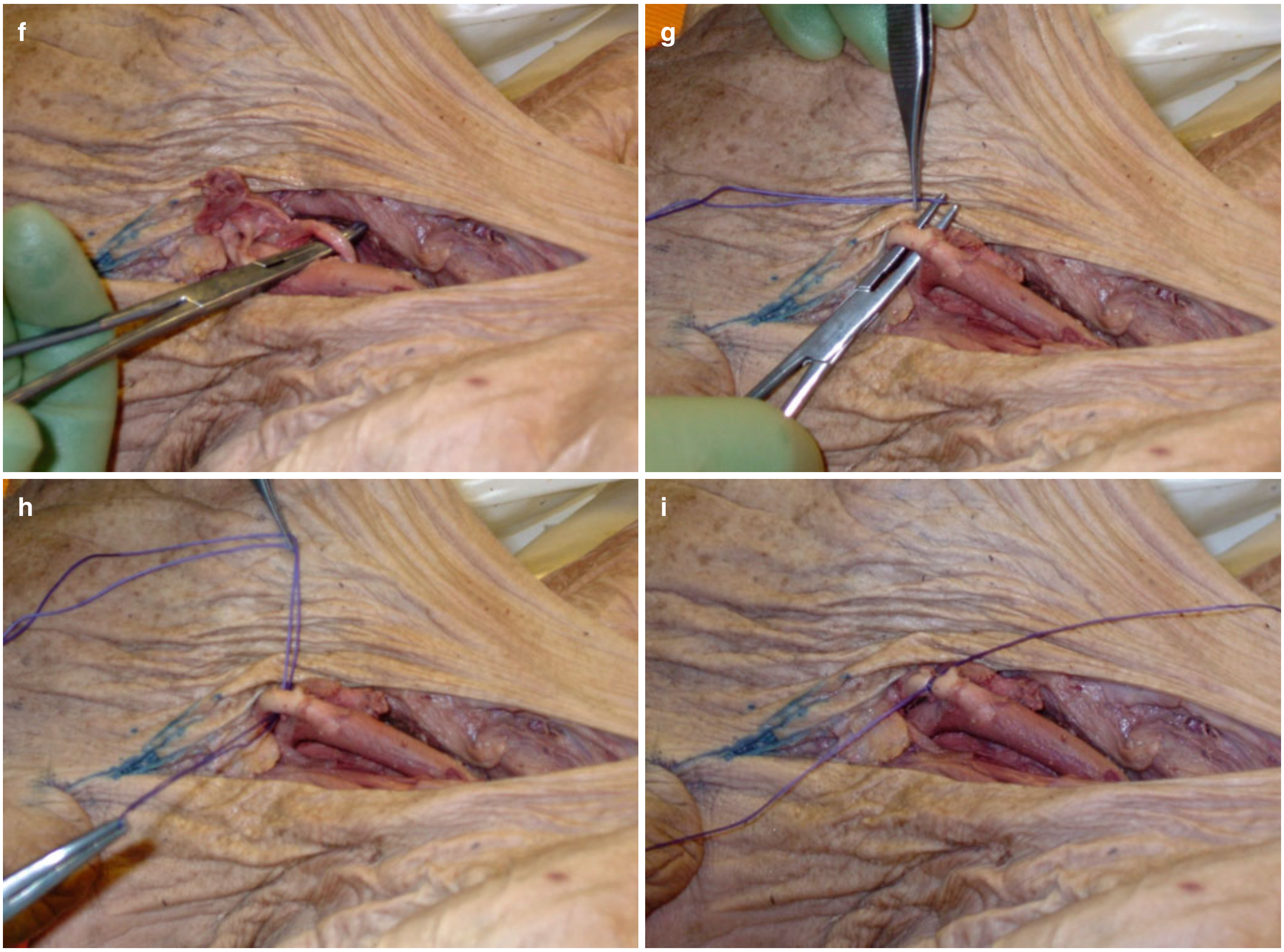

Fig. 1.42 (continued)

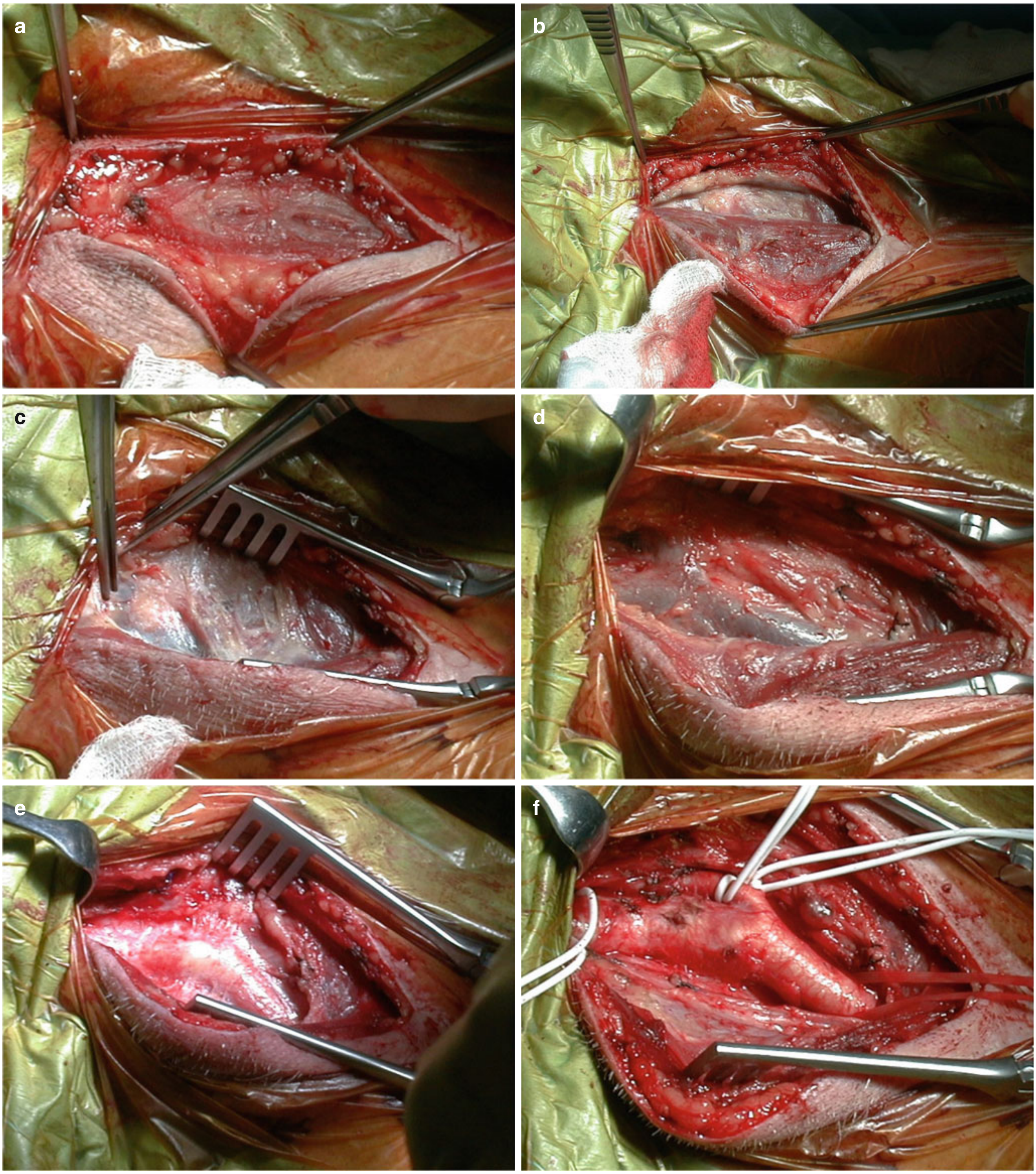

Fig. 1.43 Carotid exposure. (**a**) Initial skin incision and exposure of sternomastoid muscle. (**b**, **c**) Muscle retraction with exposure of carotid sheath. (**d**, **e**) Exposure of internal jugular vein and common carotid artery. (**f**) Slings placed for control

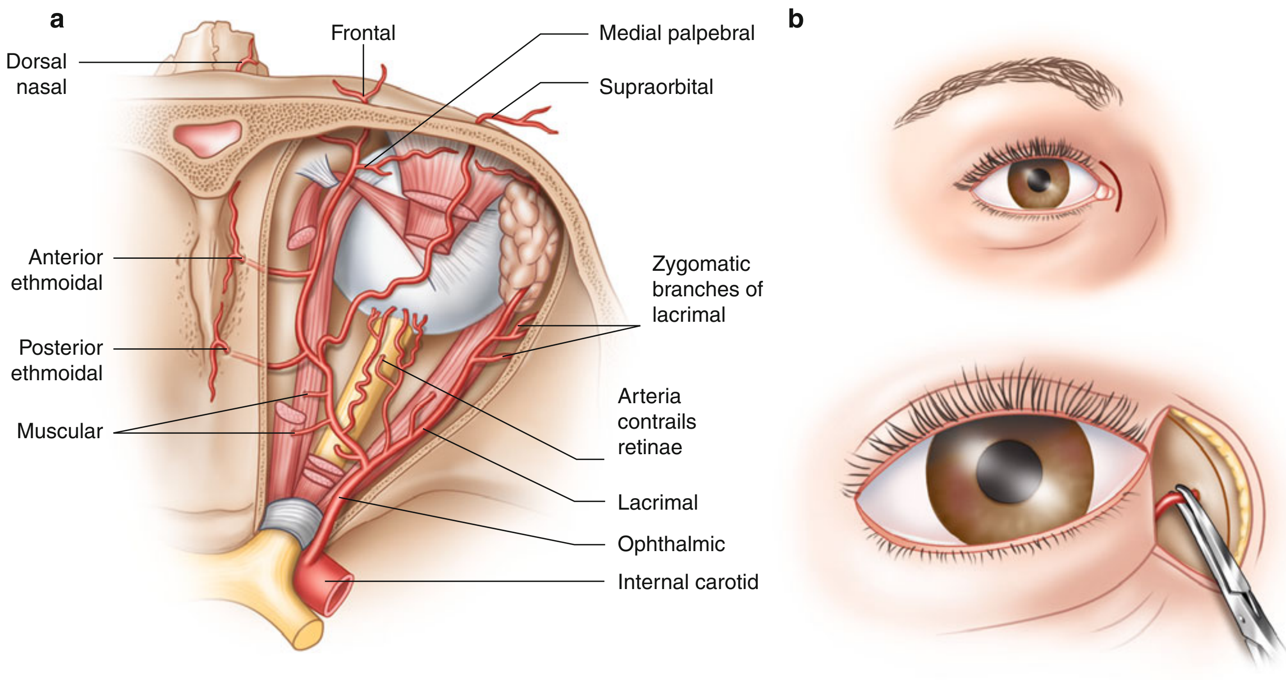

Fig. 1.44 The anterior ethmoid artery is a branch of the ophthalmic artery in the orbit (**a**). It passes through the medial orbital wall into the upper nasal cavity and can be accessed through a local incision (**b**)

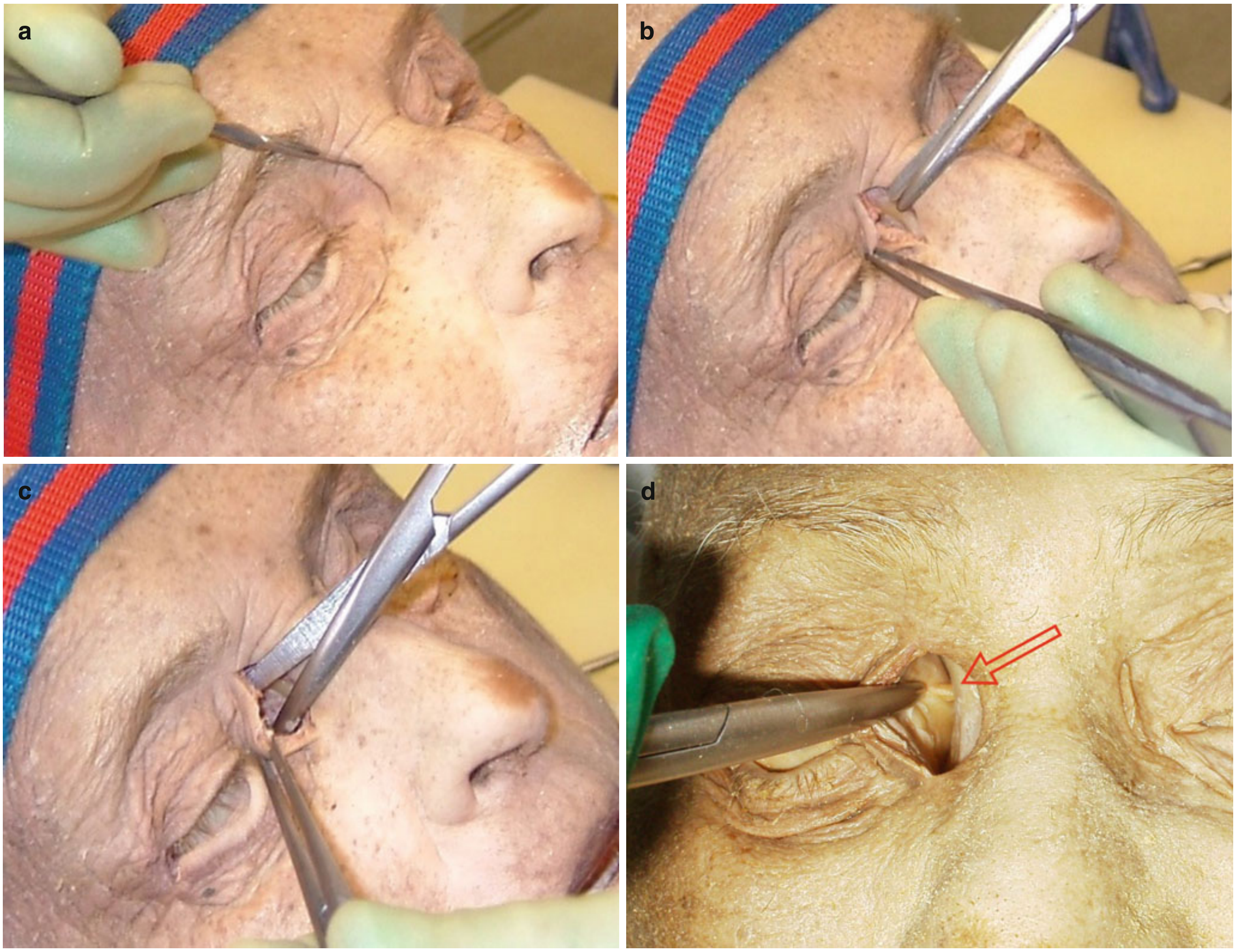

Fig. 1.45 Anterior ethmoidal artery ligation (cadaver dissection). A small curved incision is made just in front of the medial canthus (**a**, **b**). Subperiosteal dissection rapidly finds the vessel. Depending on the extent of exposure and associated injuries, the medial canthus may be disrupted (**c**, **d**)

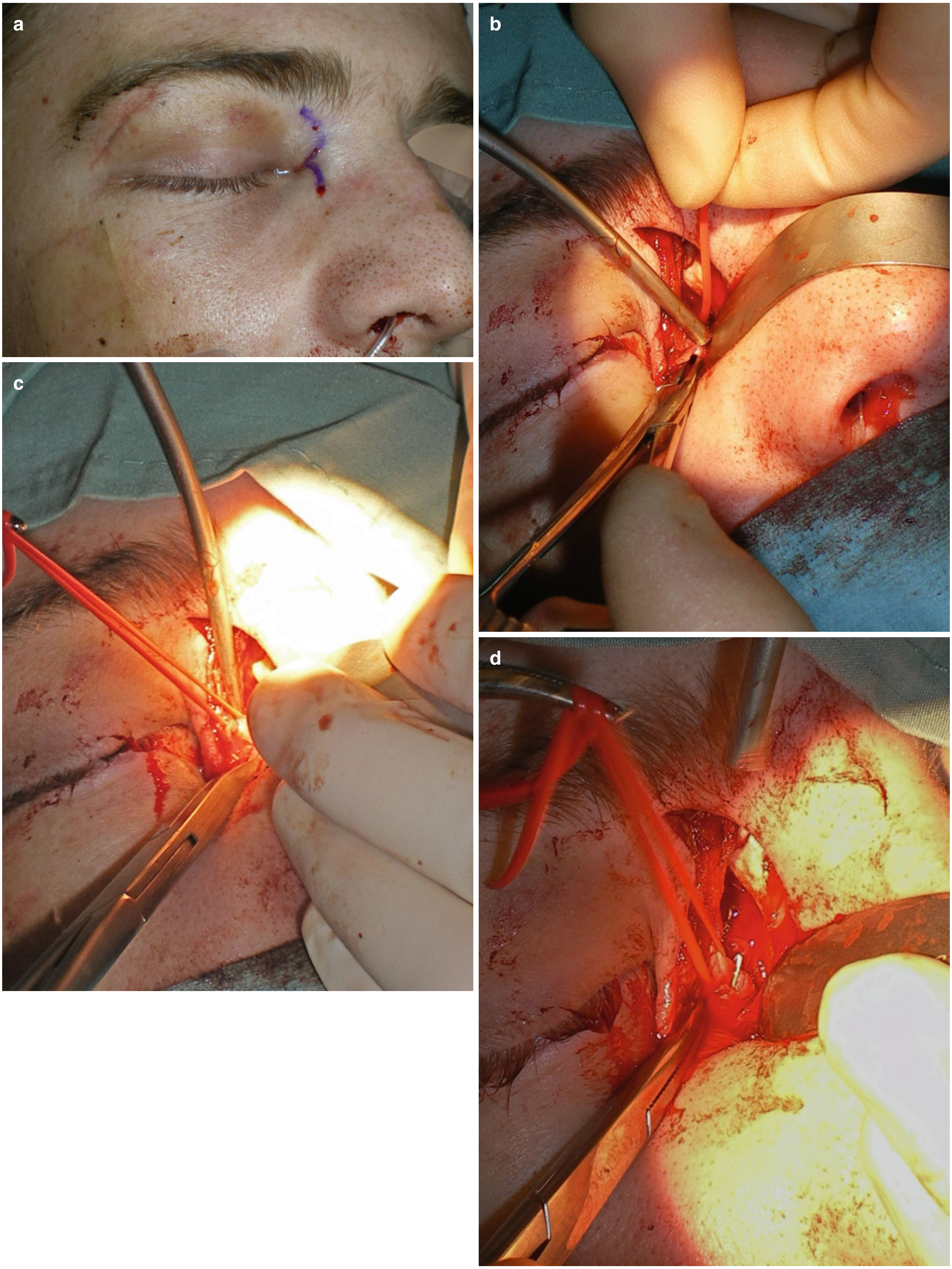

Fig. 1.46 Anterior ethmoidal artery ligation. Following incision and dissection, the vessel is identified (**a**, **b**). The vessel can be ligated, clipped or cauterised, depending on its size (**c**, **d**)

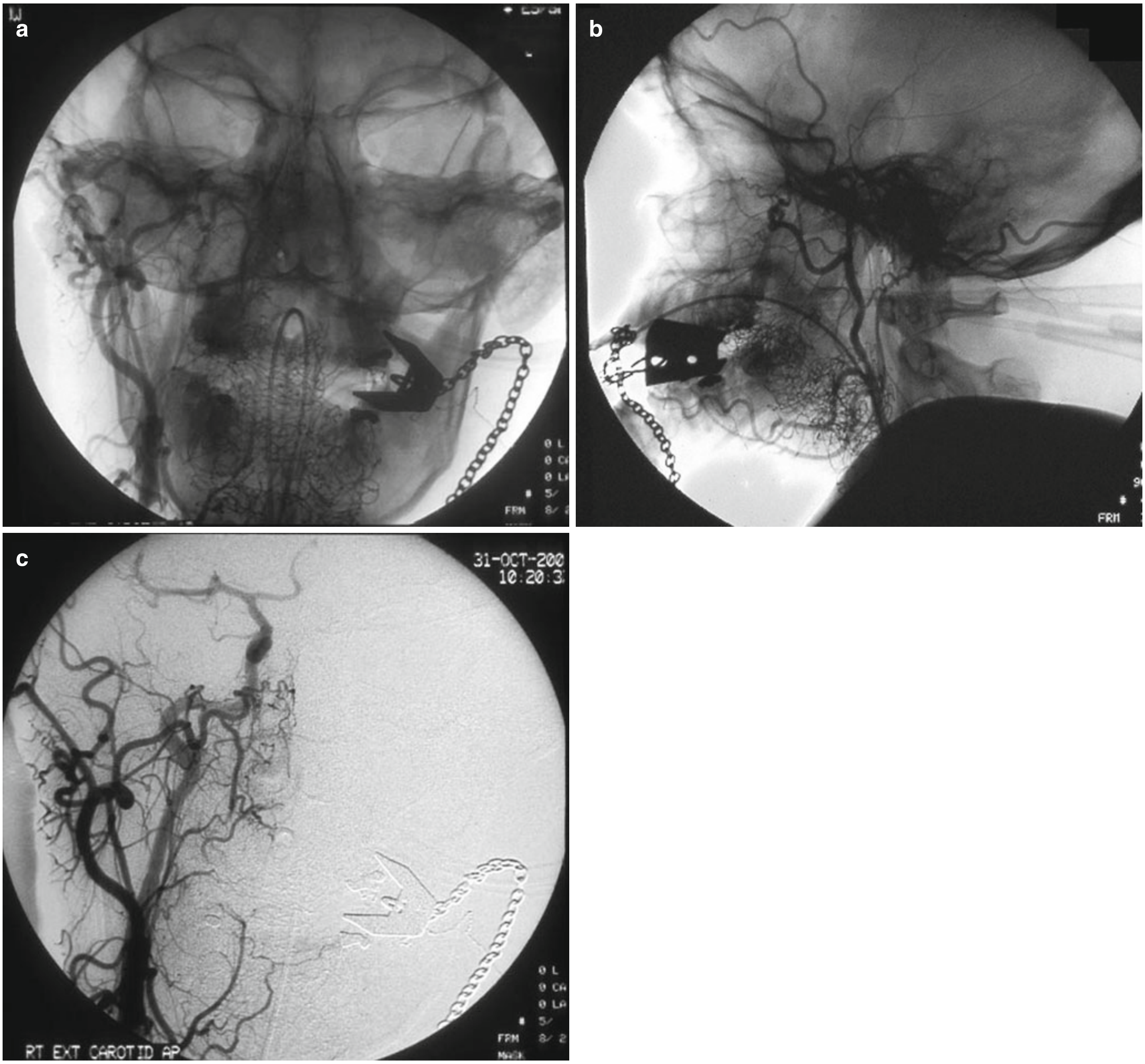

Fig. 1.47 Angiograms. (**a**) Initial angiogram showing the external carotid artery and some of its branches. (**b**, **c**) Digital subtraction techniques have considerably improved identification

1.9 Disability (Head Injuries)

The assessment and management of head and brain injuries falls outside the scope of this book, but clearly is important in trauma. Some basic principles are discussed in the chapter on craniofacial trauma. As facial surgeons we need to be aware of these and know when to call a neurosurgeon. Combined care is often required. Many centers have local guidelines and protocols and these should be followed whenever possible.

1.10 Vision-Threatening Injuries

Early recognition of vision-threatening injuries in the multiply injured patient is based on the mechanism of injury, a high index of suspicion, and gross clinical findings, rather than detailed evaluation that will need to be carried out later. In the alert patient it only takes a few seconds for a member of the trauma team to assess for vision in each eye (while assessing the GCS), check pupil size and reaction, and if the eye is proptosed, carefully palpate the globe through closed eyelids.

1.10.1 Initial Assessment

Ocular injuries range from simple corneal abrasions to devastating injuries resulting in total and irreversible loss of sight. Injuring forces necessary to damage the globe may leave the periorbital tissues relatively unscathed and unless specific attention is directed to the eye, sight-threatening injuries can easily be missed. Because of the close proximity of the structures within the anterior and middle cranial fossae to the orbit (separated by some of the thinnest bones in the body), penetrating intracranial injury must always be considered in all penetrating orbital injuries, even if it is not immediately apparent. Penetrating injuries may occur from small, high-velocity missiles at the time of the incident. These should be considered when the history reveals the presence of broken glass, wood, or metal fragments at the scene, or examination of the patient reveals eyelid or periorbital lacerations. The possibility of retained intraocular foreign bodies should also be considered if there is evidence of ruptured or penetrating globes injuries. This is important if magnetic resonance imaging (MRI) is anticipated in the evaluation of other anatomic regions (*e.g.*, spine). This imaging modality relies on intense magnetic fields and so it is essential that any metal in the orbit or skull is identified.

Vision-threatening injuries (VTIs) most commonly present with severe visual impairment or blindness immediately after injury. However, delayed visual loss is also well documented. All patients with craniofacial or midfacial injuries should therefore be commenced on regular “eye obs,” in addition to any “head injury obs.” The pathophysiologic mechanisms resulting in loss of sight and common causes of VTIs are listed in Table 1.15.

Table 1.15 Pathophysiologic mechanisms resulting in loss of sight and common causes of vision-threatening injuries

Loss of sight may be crudely considered to be due to the following mechanisms:
Direct injury to the globe
Direct injury to the optic nerve, *e.g.*, bony impingement
Indirect injury to the optic nerve, *e.g.*, deceleration injury resulting in shearing, stretching forces
As a result of a generalised or regional fall in tissue perfusion (anterior ischaemic optic neuropathy, retrobulbar haemorrhage, nutrient vessel disruption)
Loss of eyelid integrity
The more common VTIs seen in facial trauma therefore include:
Orbital compartment syndrome and retrobulbar haemorrhage
Traumatic optic neuropathy
Open and closed globe injuries
Loss of eyelid integrity

Early identification of sight-threatening conditions may be possible during the "Disability (D)" phase of the primary survey, when the pupils are assessed. Although the primary reason for examining the pupils at this stage (together with the GCS or "AVPU" score), is to assess for neurologic disability, obvious associated ocular findings can also be noted as potential "visual disability." This will facilitate early referral to an ophthalmologist for advice or assessment. Examining the pupils and GCS is therefore a convenient time to rapidly assess the visual pathway, although it is by no means a comprehensive assessment. If circumstances allow, a more detailed assessment may be possible with some simple instruments and charts, but this should never interfere with life-saving investigations and interventions.

The important signs of open and closed globe injuries that should be looked for by the nonophthalmologist are shown in Table 1.16.

In otherwise stable and conscious patients, a Snellen chart or reduced Snellen chart, for use at the bedside, enables visual acuity to be tested. Each eye is tested separately with any distance spectacles, or contact lenses, that are normally worn. If these are unavailable, small or moderate refractive errors are overcome with the use of a "pinhole." A patient who normally wears a distance spectacle and can achieve 6/24 on the Snellen chart should easily manage 6/9 or better through a pinhole if no serious pathology is present. Formal colour vision testing makes use of the Ishihara pseudoisochromatic plates. However, if these are not available, a bright red object such as a container top will suffice in the first instance. The saturation in one eye is compared with the other. This can provide useful evidence if there is a suspicion of a relative afferent pupillary defect.

Although not itself directly vision-threatening, corneal abrasions (loss of corneal epithelium) is very painful, and can prevent examination. Patients often have intense blepharospasm. If this is present there is no contraindication to placing a few drops of topical anaesthetic (*e.g.*, oxybuprocaine). Rapid pain relief is almost diagnostic. This can then be followed by a drop of 2 % Fluorescein. All but the smallest of abrasions can be seen as a green patch on the corneal surface.

Table 1.16 Warning signs of globe injury

Subconjunctival haemorrhage: may be concealing an underlying perforation or rupture
Corneal abrasion: may be associated with a more severe injury
Hyphaema (blood in the anterior chamber of the eye): present in one third of all eyes with significant (open or closed) injury
Irregular pupil: may occur in closed injuries from sphincter tears and will be "peaked" in open injuries with prolapse or loss of uveal tissue
Prolapsed uveal (pigmented) tissue
Obvious open wound
Collapsed or severely distorted globe
Shallow or abnormally deep anterior chamber
Hypotonous eye
Loss or impairment of the red reflex

1.10.1.1 Ocular Assessment in the Unconscious Patient

Visual acuity testing and colour perception are well known to be reliable tests in the recognition and documentation of loss of vision. However, these do require a patient who is fully awake and cooperative. Unfortunately, visual assessment in the *unconscious* patient is extremely difficult. It is in these patients that early and possibly treatable threats to sight may be easily overlooked. Initial clinical assessment therefore usually relies on the assessment of pupillary size, reaction to light and careful assessment of globe tension by palpation, if there is proptosis. The presence of a relative afferent pupillary defect (RAPD) is regarded as a sensitive clinical indication of visual impairment (*see* Table 1.17; Figs. 1.48 and 1.49).

Initial funduscopy is difficult to perform without dilating the pupil, (which would be contraindicated in an unconscious head injured patient), but should be attempted anyway. Funduscopy can also appear misleadingly normal, as the optic nerve takes time to atrophy. However it may be possible to detect intraocular haemorrhage, retinal oedema/detachment and avulsion or swelling of the optic disc. If funduscopy is not possible the red reflex should at least be checked and compared between each eye.

All ocular injuries require immediate ophthalmic referral. Visual loss is the next priority once life- and limb-threatening problems have been addressed. Arguably, VTIs are just as important as limb-threatening problems, especially if they are present bilaterally. Both impede rehabilitation and dramatically reduce the quality of life.

Table 1.17 How to check for a relative afferent pupillary defect

Shine a bright pen torch in to the eye from the side
Swing the torch rapidly on to the other eye and keep alternating
Allow at least 3 s of illumination on each eye
With the light on the healthy side, both pupils constrict
With the light on the diseased side, both pupils dilate

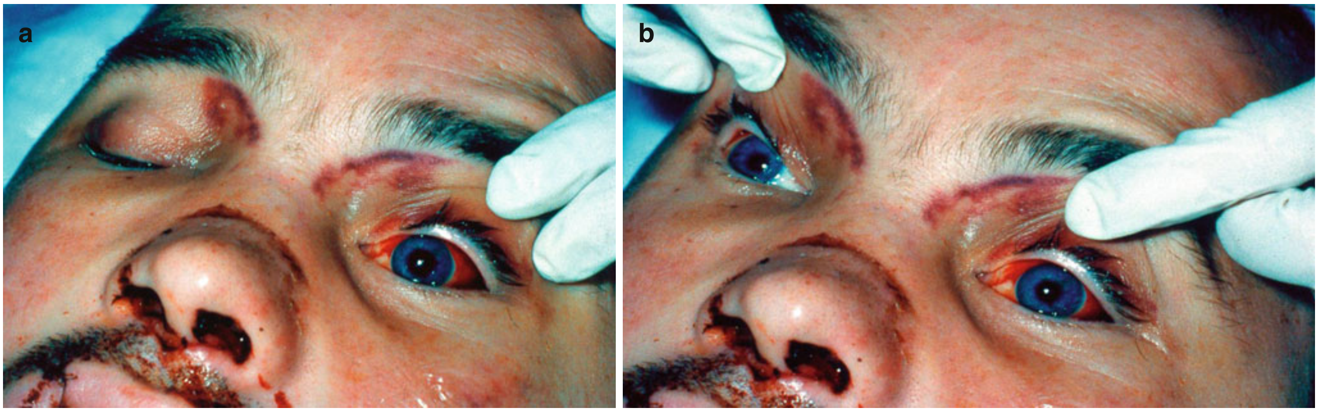

Fig. 1.48 Relative afferent pupillary defect (RAPD). This is regarded as a sensitive indicator of visual impairment. It should be looked for routinely in all unconscious patients with head or facial injuries (**a**). Note left pupil has constricted on opening the opposite eye (**b**)

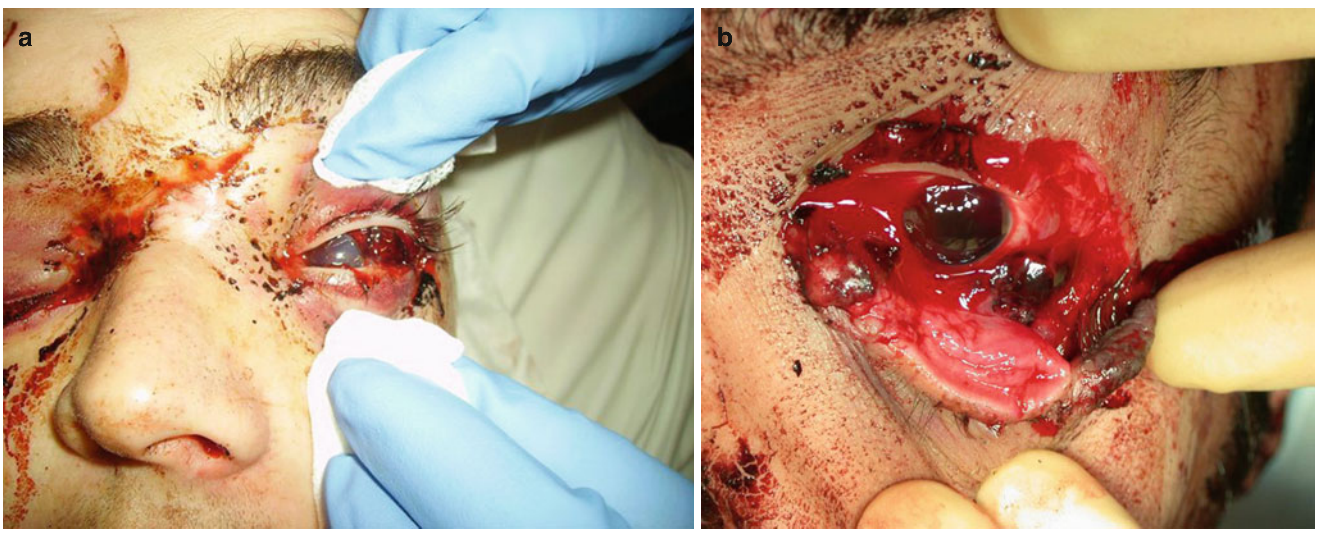

Fig. 1.49 Clearly these are major globe injuries (**a**, **b**). The precise diagnosis is not important at this stage, but protection of the globe and immediate referral to an ophthalmologist is

1.10.2 Proptosis, Orbital Compartment Syndrome, and Retrobulbar Haemorrhage

> Critically raised retrobulbar pressures need to be recognised and treated promptly. Irreversible optic and retinal ischemia can occur within 60 min and permanent visual loss within 1.5–2 h. It is generally accepted that outcomes are usually better the earlier treatment is started.

Proptosis following trauma has been reported to occur in approximately 3 % of craniofacial injuries. However, *vision-threatening* proptosis is a much rarer event. Nevertheless, when it occurs urgent intervention is required if loss of vision is to be prevented. Usually proptosis is apparent by the time the patient arrives in the emergency department, but delayed presentation of up to several days has been reported.

1.10.2.1 Pathogenesis

The orbit is a (mostly) rigid box, except anteriorly where the orbital septum and eyelids are more elastic. Although there are several fissures and foramina, similar pressure–volume relationships to those seen in other "closed" body compartments can occur. The orbit is therefore an anatomical region that is at risk of developing a compartment syndrome. Due to its reduced capacity to accommodate additional volume, any increase in volume (from bleeding or swelling) will quickly result in a rapid rise in interstitial pressure. This decreases the perfusion pressure, resulting in ischaemia and eventually infarction. Proptosis also occurs to a variable extent as the globe becomes pushed forward. Re-establishment of perfusion is essential if sight is to be saved.

Proptosis following trauma has a number of causes. Each requires different management (*see* Table 1.18 and Fig. 1.50).

Table 1.18 Causes of acute proptosis in trauma

Bony displacement into the orbit (blow-in fracture)
Bleeding into the orbit (retrobulbar haemorrhage)
Oedema of the retrobulbar contents
Frontal lobe herniation with skull base fractures
Orbital emphysema
Carotid-cavernous fistula
Extravasation of radiographic contrast material
Proptosis has also been described as a complication following prolonged spinal surgery in the prone position

Despite these varied pathologies, the "final common pathway" that ultimately results in loss of vision, is ischaemia. However, the treatment required in each case varies. From our perspective, one of the most important differentiations to make is between retrobulbar *haemorrhage* (RBH), (which may need evacuation) and retrobulbar *oedema* (which may resolve medically, or require a different surgical procedure). Traditionally, the tense, proptosed, nonseeing eye with a nonreacting dilated pupil, following facial trauma (or its repair) is taught to occur as a result of acute bleeding within the orbit—an RBH. This is considered to be a surgical emergency that (depending on the patient's general condition and likelihood of salvaging vision), may require immediate decompression. It is also commonly taught that treatment should never be delayed in order to undertake investigations. Following immediate lateral canthotomy and cantholysis, medical measures are instituted while preparing the patient for surgery.

1.10.3 Lateral Canthotomy

Lateral canthotomy with lateral canthal tendon division can be performed under local anaesthesia in the emergency department. Lignocaine 1 % with adrenaline (1 in 200,000) is injected into the lateral canthal area of the affected eye and the lateral canthus is incised to the orbital rim and the identified canthal tendon cut. The tendon is identified by "strum-

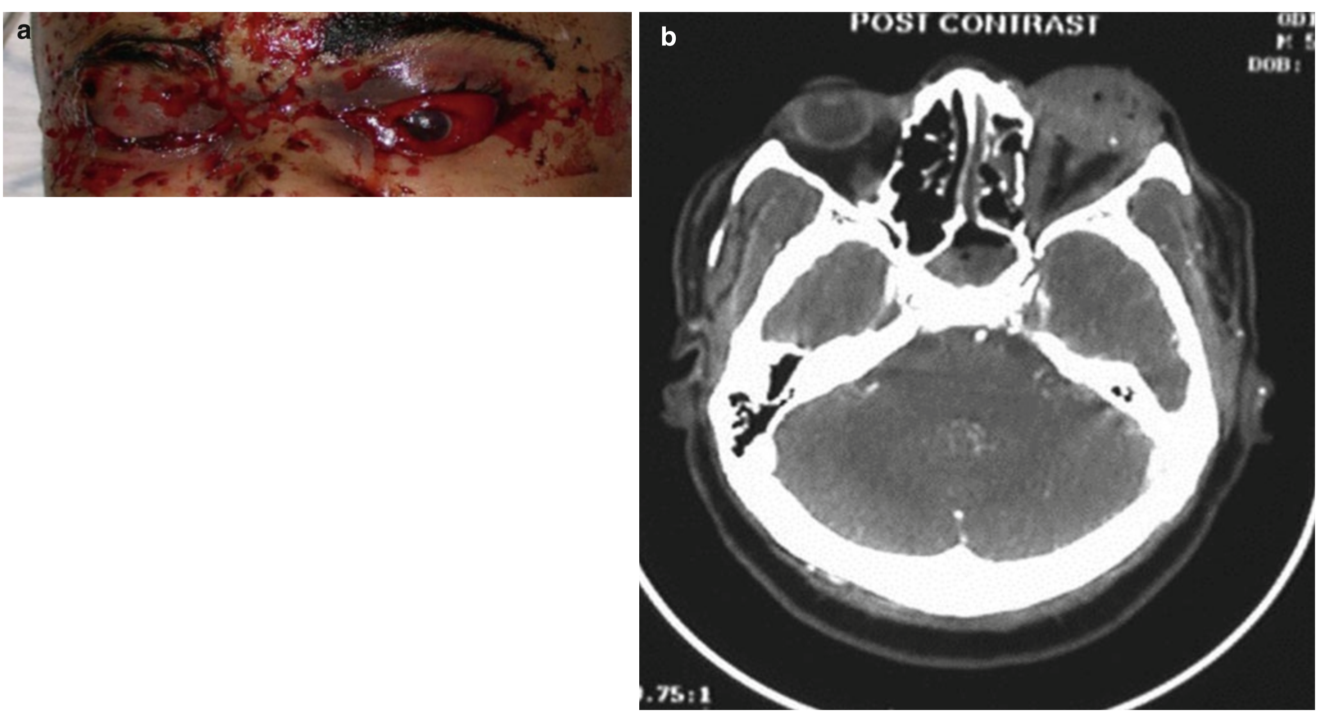

Fig. 1.50 Acute proptosis. (**a**) Patient at presentation. (**b**) CT scan. The globe needs immediate protection and possibly a lateral canthotomy (although it also looks internally disrupted)

ming" the tissues, while the eyelid is pulled medially and out. Great care must be taken to avoid damage to the globe. The lower crus is always divided and some authorities recommend division of the upper crus as well. This allows the globe to translate forward, partially relieving the pressure by effectively increasing the retrobulbar volume (*see* Figs. 1.51 and 1.52).

Formal evacuation of the haematoma is then carried out under a general anaesthesia. The orbital and intraconal spaces are opened, allowing blood and oedema to

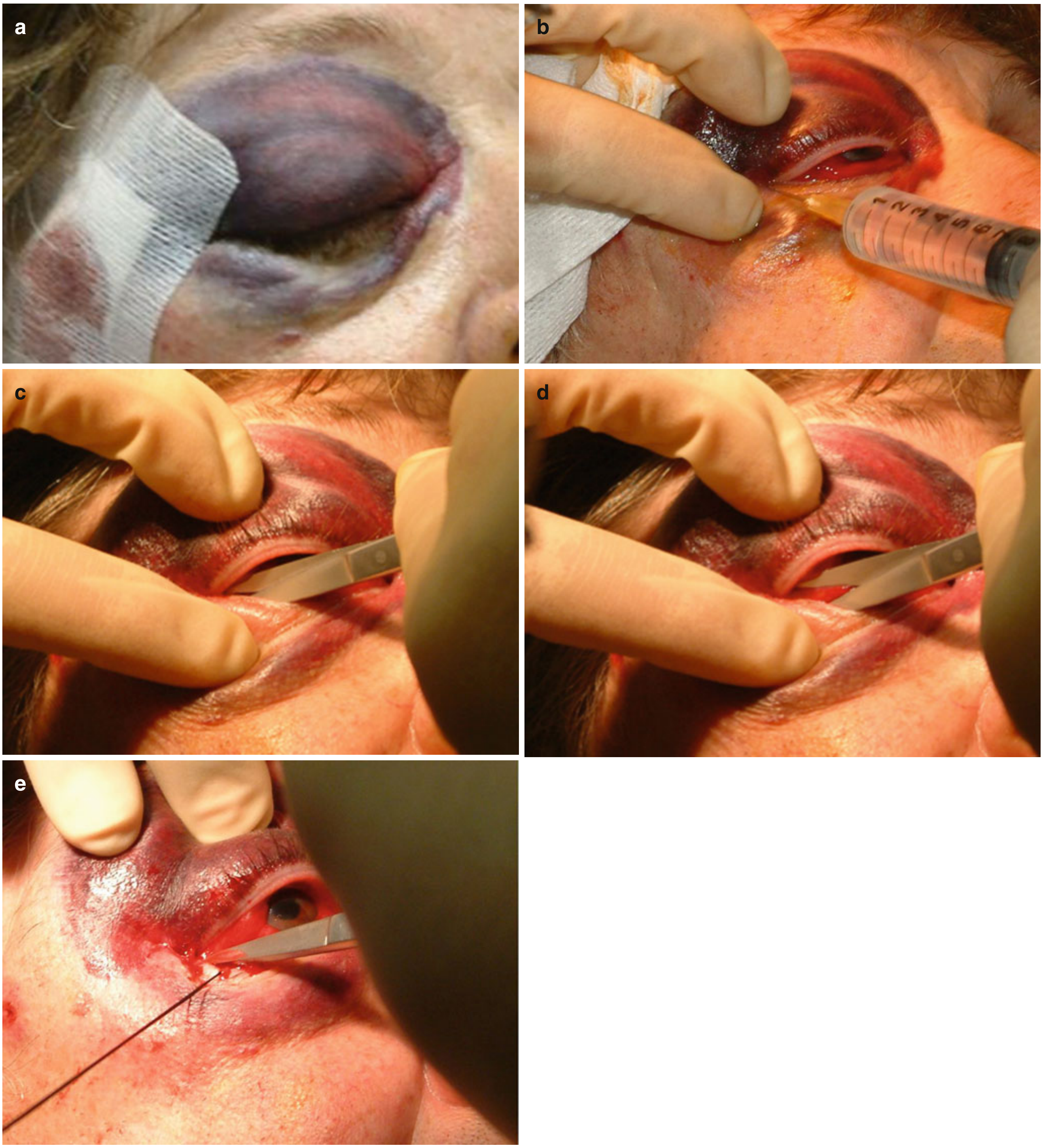

Fig. 1.51 Proptosis (case 1; *see* Fig. 1.2). A tense proptosed globe with decreased vision needs immediate treatment (**a**). Local anaesthetic is given (**b**). (**c**, **d**) The lateral canthus is detached using sharp scissors. (**e**) A traction suture on the lower lid helps separate the tissues. When this is successful the globe "pops" forward

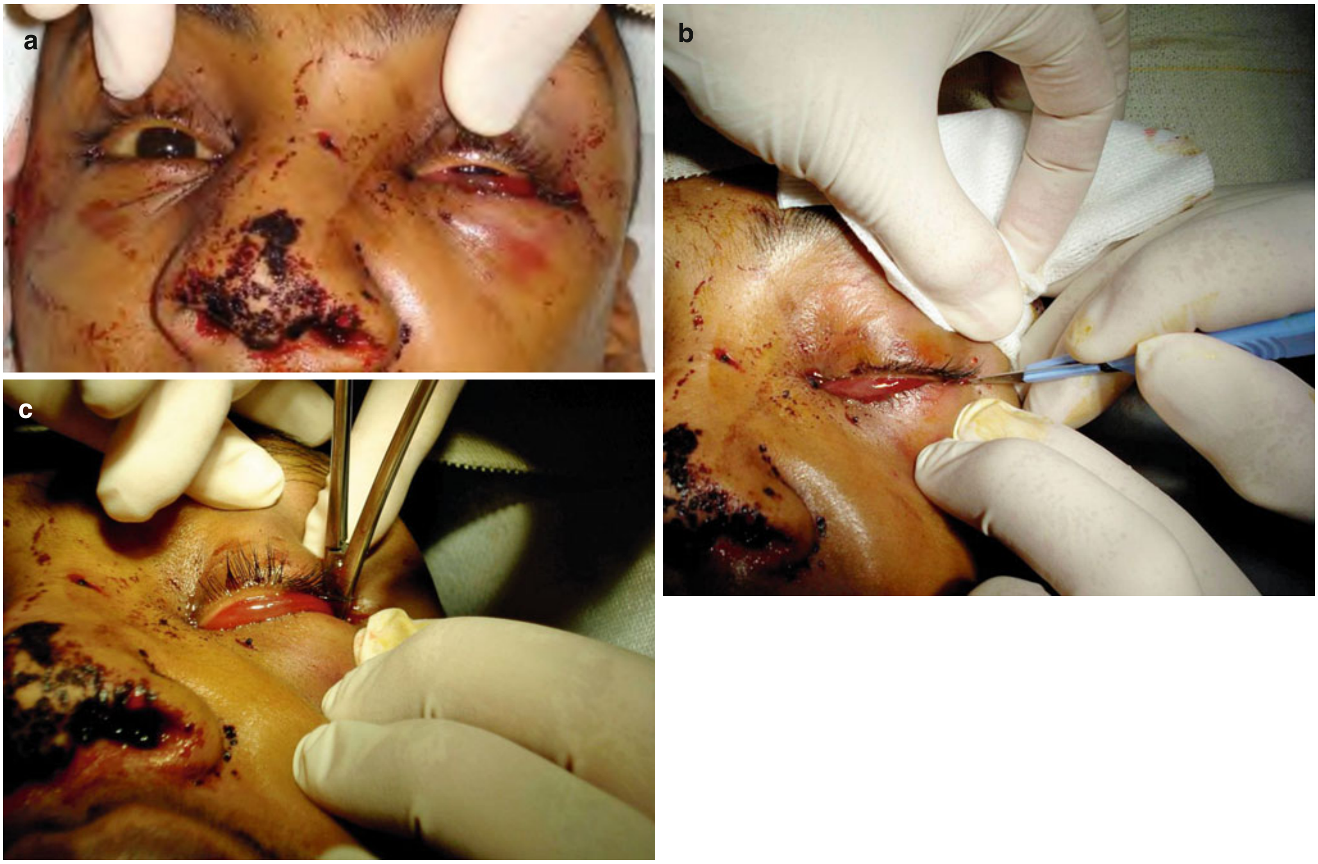

Fig. 1.52 Proptosis (case 2). (**a**–**c**) This technique is variably described in the literature. Detachment of Lockwood's ligament may be required to ensure the globe is free to move

escape. Drains may be placed. Various approaches are possible (*see* Fig. 1.53), the infraorbital approach is the most commonly used.

Unfortunately being such a rare condition, very few of us (including the authors) are true experts in this area, making clear evidenced-based guidelines difficult to establish. However, it is worth remembering that not all cases of "tense" proptosis following trauma are due to RBH. Previous reports have shown that many cases of proptoses are actually secondary to *oedema* within the retrobulbar tissues. This has major implications in how patients are managed. Therefore the term *orbital compartment syndrome* (OCS) is very useful. This is more accurate and conveys the sense of urgency when communicating with colleagues unfamiliar in the management of facial trauma.

Differentiation between RBH and OCS on clinical grounds alone is not always possible. Not surprisingly, both share similar features (*see* Table 1.19).

Fig. 1.53 Emergency decompression. In this case, drainage was achieved through an upper lid approach. Usually a lower approach is undertaken

Table 1.19 Clinical features of retrobulbar haemorrhage and orbital compartment syndrome

Decreasing visual acuity
Pain
Ophthalmoplegia
"Tense" proptosis
Development of a relative afferent pupillary defect (RAPD)
Swollen or pale optic disc
In the unconscious or poorly responsive patient this is limited further to
"Tense" proptosis
Development of an RAPD
Swollen or pale optic disc

1.10.4 Initial Assessment of Proptosis in the Unconscious Patient: Dilemmas and Decision Making

Care is required when assessing the eyes in the elderly. In some patients a dilated pupil itself may precipitate ocular problems. Acute angle closure glaucoma can be precipitated by dim light, and some drugs. This should be considered in any elderly patient who develops a painful, tense, "red eye."

Comprehensive assessment of proptosis in the emergency department, intensive care unit, or operating theatre is usually not possible in the early stages of management. What is possible is often limited, even more so if the patient is confused, agitated, or unresponsive. In awake patients, clinical urgency can be determined by deterioration in visual acuity. However, in the unconscious or agitated patient, this is not possible. Pain and ophthalmoplegia, two further indicators of vision-threatening proptosis, also cannot be determined. It is also worth remembering that a well-made prosthetic eye can fool all but the most astute of clinicians!

In unconscious patients, initial assessment is therefore significantly restricted to a relatively crude examination, including assessment of the eyelids, pupils, careful palpation of the globes and, if possible, funduscopy (or portable slit lamp examination). Each has its limitations. In many patients, the only readily identifiable signs of a retrobulbar haemorrhage or orbital compartment syndrome will be a "tense" proptosed globe with an abnormally reacting pupil and swollen disc (*see* Table 1.20).

In some patients, examination of the pupils can be misleading. Traumatic mydriasis, alcohol, recreational drugs,

Table 1.20 Ocular assessment in the unconscious patient: a checklist

Lid oedema/injuries
Foreign bodies
Chemosis (conjunctival oedema)
Pupils: size and reaction
Relative afferent pupillary defect
Globe tension: carefully palpate if not contraindicated (*e.g.*, rupture, penetration, or perforation)
Funduscopy (if possible)
Consider glaucoma in the elderly and remember the effects of drugs

opiates (for pain relief), or paralyzing agents can all affect pupil size and reaction. "Sluggish" pupillary responses are also very subjective in nature, and open to misinterpretation. Nevertheless, the presence of a correctly elicited RAPD indicates impaired optic nerve function.

A brisk reaction to direct and consensual light stimuli, in a round, concentric pupil can be regarded as reliable in excluding VTIs requiring immediate intervention.

In most cases in which proptosis is present, this is usually mild and no active intervention is required. Unfortunately, the relationship between proptosis and retrobulbar pressure is not linear. By way of analogy, vision-threatening ischaemia in thyroid eye disease can occur in the *absence* of significant proptosis. One of the main clinical problems in the unresponsive patient is therefore deciding whether a proptosis is "tense" enough to warrant risks of urgent surgery. In some patients, the globes may be gently palpated, but this is contraindicated if penetrating/perforating injuries or a burst globe are suspected.

Palpation of the globes is also a very subjective measure of IOP (and by inference retrobulbar pressure). Terms such as "stoney hard" are open to misinterpretation and can mislead. Portable tonometry, commonly used to measure the IOP, may give some indication of retrobulbar pressure, although IOP does not precisely reflect this. Handheld IOP-measuring devices are now available and reported to be reliable. Currently accurate determination of retrobulbar pressure is only possible using a "slit catheter," which measures the pressure directly. This is really more of a research tool (*see* Fig. 1.54).

Although a raised IOP secondary to glaucoma can also confuse the clinical picture, it has been reported that in the proptosed eye, a pressure of 40 mmHg or more indicates critical ischemia and the need for urgent treatment (By

Fig. 1.54 Portable tonometry may be useful in the assessment of proptosis

comparison, orthopaedic surgeons regard an interstitial pressure of 30 mmHg or more, as an indication for urgent fasciotomy in acute compartment syndrome). Irrespective of the pressures, signs of deteriorating vision (RAPD) indicate the need for immediate treatment.

Further assessment if time allows may include CT scanning. The role of CT in the assessment of head injuries has expanded considerably during the past 20 years. Numerous guidelines on this subject are now available. With helical scanners, scanning times have been significantly reduced and this has facilitated early imaging of the injured face. However, orbital CTs only define anatomy and not function (*see* Fig. 1.55). They provide no indication of tissue perfusion. B-scan ultrasonography has also been reported as another valuable tool, but this is not commonly used. It is a painless, well tolerated, relatively quick, noninvasive test that can assess the location, size, and configuration of any orbital masses. This may help in the planning of any urgent decompression.

> Any patient requiring a brain CT, who has suspected periorbital or ocular injuries, should also undergo imaging of (at least) the orbits at the same time. Additional scanning times for this are now negligible. Globe rupture, optic nerve transection, intraocular haemorrhage, intraocular foreign bodies, periorbital and orbital apex fractures and the nature of any proptosis are all readily identifiable.

In awake patients, clinical urgency of any ocular injury is usually determined by the patient's vision. This is because the most important prognostic factor has been reported to be the amount of damage to the macula or optic nerve at the time of injury. In the unconscious patient this cannot be determined. However, visual evoked potentials (VEPs) have been reported to be reliable in the assessment of the visual pathway. This is now a well-established investigation in the diagnosis of multiple sclerosis (MS) and epilepsy, although it has some limitations. Flash VEP is regarded as the most reliable predictor of vision, followed by the bright-flash electroretinogram. Its value is in its ability to identify early problems in the anterior visual pathway, although this is nonspecific. It is an objective and reproducible test, and in craniofacial trauma VEP has been reported as a useful adjunct in early detection of visual loss. This complements imaging by determining the functional impact of any globe or orbital abnormalities seen on the scans. Unfortunately, the equipment required is somewhat cumbersome and not ideally suited for rapid evaluation in the emergency room.

CT therefore defines anatomy and possible causes of vision-threatening injuries, and helps plan surgery. Tonometry may give an indication of urgency by reflecting tissue perfusion, and VEP tells us whether vision is at risk and urgent evaluation is required. Unfortunately, obtaining all three investigations on an urgent basis is probably difficult in most centers. Sound clinical judgement is therefore still required to determine which patients may benefit from immediate intervention. Clinical judgement is also required

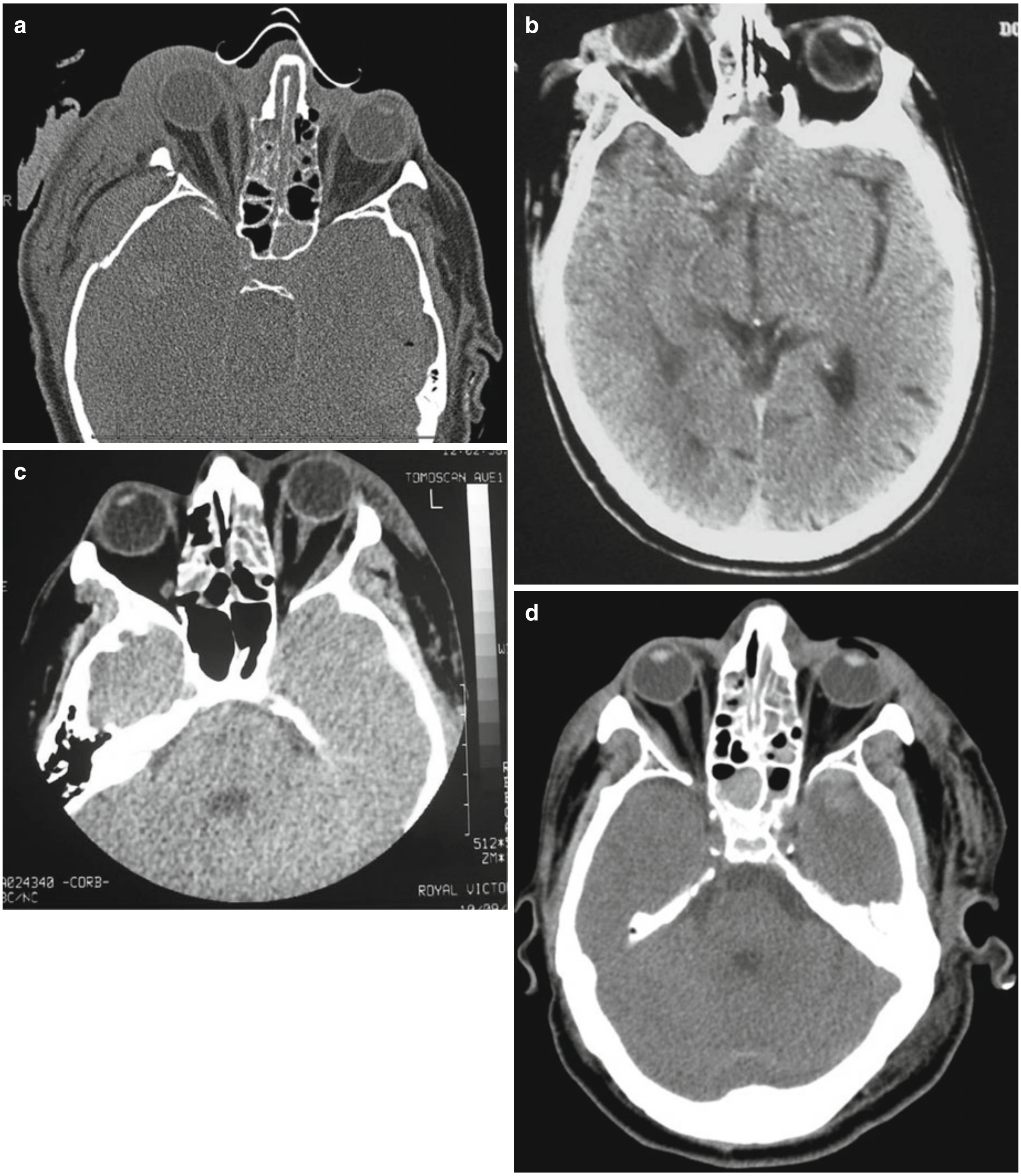

Fig. 1.55 (**a**–**d**) Several cases of acute proptosis following trauma. All required urgent computed tomography to evaluate their head injuries. In all cases, the clinical findings were interpreted as a possible retrobulbar hemorrhage. Yet in all these cases there is no blood. This has major implications in cases where there is no imaging available but urgent treatment is necessary. In the last example, stretching of the optic nerve and a tenting of the posterior sclera represent the so-called "balloon on a string" sign

to decide whether it is in the patient's best interests to postpone treatment until further examination and investigations have precisely determined the extent of their ocular/orbital injuries. On the other hand, treatment of some clinical findings (*e.g.*, a "very" tense proptosed globe) should not be delayed while waiting for investigations. In these cases, treatment should be commenced as soon as possible.

Computed tomography, tonometry, and flash VEPs therefore have complimentary roles in the assessment of proptosis in the unconscious patient. Together they help determine "who" needs surgery and "how" it is best done.

1.10.4.1 Why Is the Distinction Between Retrobulbar Haemorrhage and Orbital Compartment Syndrome Important?

The traditional teaching is that RBH is a clinical diagnosis that requires an immediate lateral canthotomy and cantholysis, initiation of medical measures, and urgent evacuation of the haematoma. *Investigations should not delay treatment*. Imaging is undoubtedly beneficial, but this may be very difficult to get within the time constraints required to save vision.

Medical treatments and a lateral canthotomy may "buy time" while preparing the patient for theatre (*see* Table 1.21). Mannitol and acetazolamide are frequently prescribed, but in the presence of hypovolaemic shock may be contraindicated. High-dose steroids are recommended but these are now contraindicated if the patient has coexisting severe head injuries. While "lateral canthotomy" and "cantholysis" is also recommended, the anatomy and technique is variably described in the literature and maybe confusing to those inexperienced in the technique (*i.e.*, most of us).

When urgent surgical decompression is needed, the distinction between RBH and OCS becomes important. If CT scans have not been performed, a risk-benefit analysis is required to decide whether decompression is appropriate, safe, and should be attempted on clinical grounds alone. Bleeding in RBH can be either intra- or extraconal, the former believed to have a worse prognosis. Extraconal blood can collect anywhere within the extraconal space, and drainage may be difficult to attain through an inappropriately sited incision. Initial evacuation of blood is usually undertaken through a lateral approach, since this is considered to be safer. However, if proptosis has occurred as a result of bleeding medially, or it is secondary to oedema, this approach will fail. This may then result in diagnostic confusion. If blood is not easily drained, an alternative or additional approach will need to be considered. Decompression must still be achieved.

> Patients should not leave the operating table until the proptosis has shown obvious signs of improvement, or the clinician feels that the sight is no longer salvageable, or other overriding general factors require surgery to stop.

For patients in whom investigations are not immediately available, a number of dilemmas can arise (*see* Table 1.22).

Irreversible ischaemia in OCS is in many ways analogous to that seen in the head-injured patient with a critically raised intracranial pressure. In the severely head-injured patient, it is known that maintaining the mean systolic blood pressure above 100 mmHg is essential to maintain cerebral perfusion. Any fall below this significantly increases the mortality. This raises the question—in the presence of a proptosis, does a low mean systolic blood pressure (following hypovolaemia in the multiply injured patient) have the same affect on visual disability as it does with neurological disability in head injuries? Is there a minimal "orbital perfusion pressure" that is necessary to prevent visual deterioration? This has not been reported in the literature, but has significant implications on how (or whether) to treat any proptosis. Sudden and profound episodes of hypotension from a variety of nontraumatic causes have also been reported to result in loss of sight all in the *absence* of craniofacial trauma—are these risks greater following trauma?

Table 1.21 Initial management of acute proptosis

High-dose intravenous steroids
Acetazolamide (250–500 mg)
Mannitol (1 g/kg)
Lateral canthotomy and cantholysis

Table 1.22 Clinical dilemmas in proptosis

When is a proptosis severe enough to warrant urgent surgical decompression on clinical grounds alone? If decompression is deferred, repeated examination is necessary, since swelling will initially get worse.
When is swelling at its maximum and the globe most at risk? This is not clear in the literature, although 36 h is sometimes quoted.
How is decompression best achieved, if the underlying cause (bone, blood, oedema, air or frontal lobe) is not known?
If decompression is not undertaken, will the resulting chronic ischemia result in muscle fibrosis and contractures, much akin to the Volkmann's ischemic phenomenon? ("Orbital Volkmann's.") This has been described.
Does the patient's systemic blood pressure affect orbital perfusion and the decision to decompress (or not to)? In a limb, it is known that relative ischaemia can occur if the diastolic blood pressure falls. In the orbit, if the mean arterial pressure falls below the intraorbital pressure, retinal perfusion may be impeded.

1.11 Traumatic Optic Neuropathy

Traumatic optic neuropathy (TON) occurs in approximately 0.5–5 % of closed head injuries. These can sometimes be relatively trivial in nature. Visual loss is permanent in approximately half. TON occurs when injuring forces transferred to the optic canal results in damage to the optic nerve. Stretching, contusion, or shearing forces can injure the nerve as it passes through the relatively thick bony canal into the orbit. These initial insults then initiate a cascade of molecular and chemical mediators, which cause secondary vasospasm and vaso-occlusion, with edema, and necrosis. This can result in intraneural compression, vaso-occlusion, and a local form of compartment syndrome, which is initially reversible. However, this progresses over time to arterial obstruction and finally to irreversible infarction.

Deceleration injuries and blunt trauma to the face and head are the common causes of TON. Motor vehicle collisions, falls, and assault account for the majority of cases. Displaced fractures around the orbital apex and associated oedema can also directly compress the nerve, compromising its vascular supply. Less commonly, nerve sheath haematoma or complete transection can occur. With the exception of complete nerve avulsion, these different types of injury cannot be distinguished clinically and CT scanning is usually necessary.

Diagnosis of traumatic optic neuropathy is a clinical one. Loss of consciousness following a significant head injury is a common association. Visual loss is usually profound and almost instantaneous, but it can be moderate and delayed. Clinical findings that suggest an optic nerve injury include decreased visual acuity and a relative afferent pupillary defect. Swelling of the eyelids can make examination very difficult, and with a swollen, poorly seeing eye, other causes of reduced vision such as RBH or open and closed globe injuries should also be considered. When the eye appears normal but there is reduced vision and an afferent pupillary defect, injury to the nerve near the optic canal should be suspected. Optic nerve avulsion, or nerve compression resulting in nerve head swelling or central artery and vein occlusion are readily recognisable on funduscopy. Visual fields and colour vision testing are usually not possible, as the vision is very poor. Although VEPs have been shown to be helpful in making the diagnosis, this is not widely available. CT imaging will demonstrate optic canal fractures and MRI can show soft tissue swelling and sheath haematoma.

Traumatic optic neuropathy needs immediate ophthalmic referral to confirm the diagnosis and for consideration of treatment. Treatment has long been controversial and may be medical or surgical. Medical treatment aims to reduce the oedema and inflammation that contributes to nerve ischaemia. There has been a presumed role for high-dose intravenous corticosteroid in the treatment of TON, but there is no doubt that there is now a growing consensus against this, with recent papers suggesting that steroid use may actually be contraindicated. The role of surgical decompression is even more controversial and its value cannot be judged from current evidence. Surgical approaches include transethmoidal, transcranial, or via a lateral orbitotomy, depending on the surgeons preferences, expertise available, and the individual circumstances of the patient.

1.12 Open and Closed Globe Injuries

The term "open globe injury" refers to a full thickness wound in the corneoscleral wall of the eye. This may be caused by blunt trauma (globe rupture) or by a sharp object (laceration or penetrating and perforating injury, with or without a retained intraocular foreign body). A "closed" globe injury does not have a full-thickness wound in the eye-wall and includes lamellar lacerations, superficial foreign bodies, and contusion of the globe. Generally speaking, initial poor visual acuity, presence of an RAPD, and posterior involvement of the eye, carry a bad prognosis. This holds true for both closed and open globe injuries.

Vision-threatening globe injuries may not be obvious and a high index of suspicion is required. Lid laceration, subconjunctival haemorrhage, bruising, and oedema are all commonly associated and should lead to suspicion. Blood-stained tears may indicate the possibility of an open globe injury. With an open globe injury, the eye looks collapsed; uveal tissue, retina, and the vitreous gel may be seen prolapsing out of the eye. A hyphaema and vitreous haemorrhage are also usually present and the lens may be damaged and cataractous. The IOP is low and aqueous fluid may be seen leaking from the wound when fluorescein drops are instilled. In cases of small high-velocity objects (metal and glass chips), the eye may appear intact and a small entry wound can be easily overlooked. The history is therefore important in indicating the possibility of an intraocular foreign body

(IOFB). IOFBs may be visible if the view of the fundus is clear. Ultrasound scan has been shown to be useful in detecting globe rupture, IOFBs, retinal tears and detachment, and may be required if the view of the fundus is poor. Care must be taken not to apply pressure to the eye during examination, as this can further expulse ocular contents in an open globe.

With closed globe injuries, the eyelid injuries and subconjunctival haemorrhage can be similar to those of open globe injuries. However, the globe shape looks normal. The IOP may be high due to blood blocking the trabecular meshwork in the drainage angle. Iris sphincter muscle tears, iris dialysis, hyphaema, and a displaced lens may also be present. Vitreous haemorrhage, choroidal ruptures, retinal commotio and tears leading to a retinal detachment may be visible if the view of the fundus is clear.

Management of globe injuries depends on whether the injury is open or closed. Analgesia and antiemetics should be administered and the tetanus status checked. A hard plastic shield should be taped over the eye to protect open globes, especially in children who will want to rub the eye. Patients with intraocular foreign bodies may receive prophylactic intravitreal antibiotics. Primary surgical repair of an open globe should be performed under general anaesthesia as soon as possible within 24 h after the trauma. Depolarising agents can result in tetanic extraocular muscle contractions which can expulse ocular contents and should therefore be avoided. During repair, the full posterior extent of the wound is explored and closed using nonabsorbable sutures. Foreign bodies are usually removed at the same time. Intravenous ciprofloxacin or vancomycin and ceftazidime combination is sometimes used to reduce the risk of endophthalmitis. Postoperative management aims to control inflammation, infection, pain and IOP while the eye settles. Closed globe injuries are managed with steroid, antibiotic, cycloplegic and antihypertensive eye drops.

Careful follow-up is required because endophthalmitis, retinal detachment, glaucoma, cataract and retinal membrane formation can occur. Prognosis depends on the initial degree of damage to the globe and whether any of these complications arise. Corneal scarring and irregular astigmatism lead to poor vision.

Sympathetic ophthalmitis is a rare complication occurring in 0.1 % of ocular perforations. It is characterized by uveitis in the healthy eye developing more than 14 days after trauma, and can lead to loss of vision. Early repair of the injured eye has reduced the incidence of this complication, but the role of early enucleation remains controversial. Most surgeons aim to preserve the globe after trauma for both the visual potential and better cosmesis. The British ophthalmic Surveillance Unit regarded prompt recognition and immunotherapy as effective, thus making globe retention possible.

1.13 Loss of Eyelid Integrity

Inability to effectively close the eyelids rapidly results in drying of the cornea, ulceration, and potentially loss of sight. Even relatively minor eyelid lacerations may predispose to this and may be easily overlooked. Avulsion of the eyelids is a rare but devastating injury and extremely difficult to reconstruct. Eyelid lacerations may also indicate serious underlying ocular injury. Orbital and ocular adnexal injuries occur in approximately one quarter of open globe injuries. In the presence of eyelid lacerations, assessment and management of the underlying globe is more important than that of the eyelid (*see* Figs. 1.56 and 1.57).

Visual acuity, visual fields, colour vision, ocular movements, the pupil and the fundus should all be examined in all patients with eyelid lacerations (*see* Table 1.23 and Fig. 1.58). The position, length, and depth of the wound(s) should then be documented. Medially sited eyelid injuries can damage the lacrimal drainage system and require special attention. Upper lid injuries may affect the levator muscle and its function should be noted. Full neurological examination is required if penetrating brain injury is suspected or in the presence of altered consciousness. Even small lid lacerations may be the entry wound for a significant penetrating injury and conceal a large retained foreign body. Failure to appreciate this is the main source of error when evaluating lid lacerations. Plain orbital films may reveal fractures and retained foreign bodies, but CT scan is the investigation of choice if the history suggests a significant risk of the above.

Fig. 1.57 Upper eyelids are more important than lower eyelids in terms of globe protection. Nevertheless, injuries like this can result in drying of the eye and ulceration, especially if the patient is unconscious

Table 1.23 Essential "tools" for simple eye examination

Snellen chart or bedside reading chart: for visual acuity in conscious patients
Pin-hole occluder: overcomes small refractive errors in assessing acuity
Pen torch
Fluorescein: to check for abrasions and leakage of aqueous humour
Topical anaesthetic drops, *e.g.*, oxybuprocaine: to allow assessment of patients in pain from abrasion
Direct ophthalmoscope: to better examine the anterior segment and to assess the red reflex

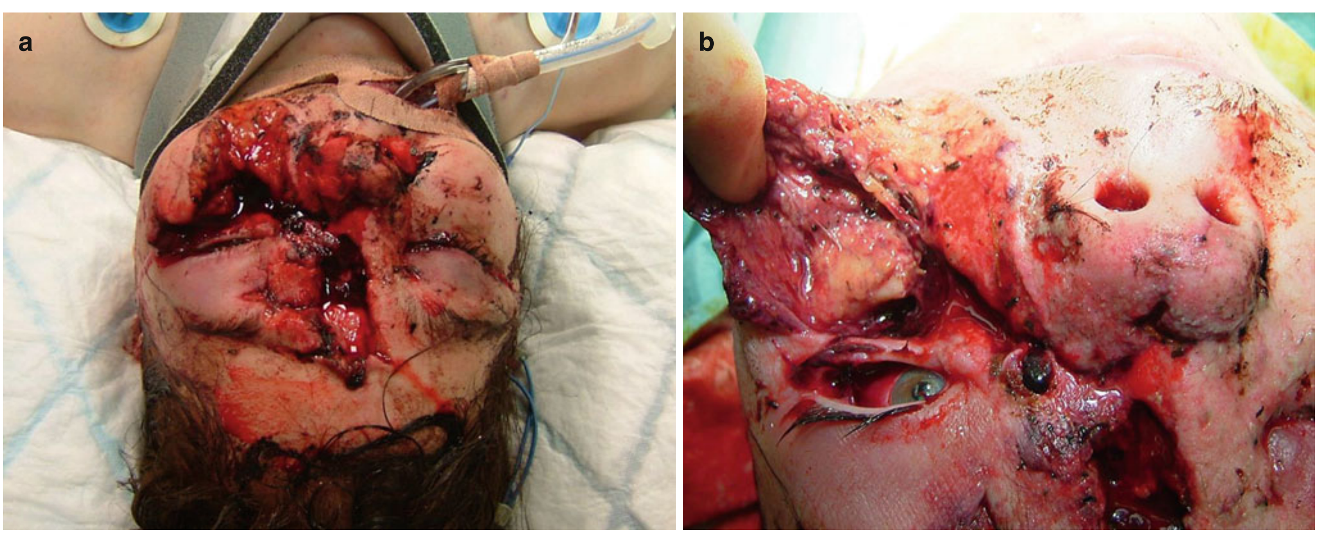

Fig. 1.56 This patient had major soft tissue injuries and extensive fractures following a motor vehicle collision into a tree. The left cheek is sagging (**a**) and the lower eyelid has no support (**b**). The airway was secured, there was no active bleeding, and the brain CT was normal. Protection of the globe was the next priority from our perspective

Fig. 1.58 Essential tools for simple eye examination

Timing of surgery depends on the general condition of the patient and the presence of other injuries. Repair of lid lacerations can be safely deferred up to 48 h (so long as the eye is protected), if other injuries take precedence. However, if unprotected, the cornea can dry very quickly, resulting in an epithelial defect, ulceration, and loss of vision. This is especially important in the unconscious patient. Under these circumstances, until the defect is repaired, eyelid remnants should be pulled over to provide corneal cover, if necessary, using a traction suture. Liberal application of chloramphenicol or artificial tears ointment should be administered and the whole area covered with a sterile wet gauze swab. If a delay in repair is expected, the wound should be cleaned and superficial foreign bodies removed. Copious amounts of saline irrigation under light pressure (using a 20-mL syringe and 18-gauge canula) can be used to wash out foreign bodies and reduce microbial load. Intravenous antibiotic cover (*e.g.*, Co-amoxiclav 500 mg tds) is needed for all bite injuries and contaminated wounds. The tetanus status should be checked.

Most simple lacerations can be explored and cleaned under local anaesthesia and closed in layers. Care must be taken to ensure suture ends do not rub the cornea and cause abrasions. Many shallow cuts can appose without the use of sutures. They scab over and heal surprisingly well as the lid is very vascular. Complex lacerations (involving the lid margin, lateral and medial canthal regions, medial third of the lids or levator muscle) must be referred for repair. These lacerations can disrupt the lacrimal drainage system and functional integrity of the lid and require detailed understanding of the functional and cosmetic anatomy of the region. As the eyelids are very vascular, even necrotic-looking avulsed tissue can survive and therefore no tissue should be excised.

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2 Timing Repair and Airway Considerations

Michael Perry

2.1 What Is the Optimal Time to Repair Facial Injuries?

The past 20 years or so we have seen major changes in the management of trauma patients, and in some specialties, long-standing practices are now being challenged. In the general trauma literature, for instance, there is now debate over the relative merits of "early total care" versus "damage control" in the management of the multiply injured patient (*see* Table 2.1).

In the severely injured, or multiply injured patient, it is argued that the main priority should initially be the rapid control of haemorrhage and the elimination of significant contamination to prevent septic shock. This is termed "damage control" and may involve for example, rapid external fixation (e.g., of the pelvis), packing the abdominal cavity, and dealing with faecal contamination. Because the patient is in such a severe condition, the added physiological insult of surgery is kept to a minimum—just long enough to deal with these life-threatening problems.

Following such "damage limitation surgery," the patient is then transferred to the intensive care unit for further resuscitation. This enables the patient's clinical condition to be optimised, prior to any lengthy, definitive repair (which carries risks of further blood loss, hypothermia and other complications). Complex surgery is therefore deferred until the patient is as well as possible. "Second look" laparotomies and fixation of fractures are then undertaken a few days later, when the patient is (hopefully) in a better condition.

Certainly in those patients who present "in extremis," this would seem a logical approach, but with less severely injured patients, the benefits are less clear. In these patients, other studies have, in contrast, suggested that early and comprehensive (or "total") repair is preferable. This approach to management avoids repeated surgery, and is argued to reduce overall mortality and morbidity.

Which is best is currently open to debate. Furthermore, the relative merits of these two philosophies seem to vary among different specialties.

In the maxillofacial literature, there has been a move toward early and total repair of facial injuries, often within the first few days, and in some cases within 24 h, of injury. A number of reviews have suggested that this approach results in significantly improved functional and aesthetic outcomes, compared to waiting 1 or more weeks before undertaking repair. Certainly, some injuries (e.g., open contaminated wounds and persistent bleeding) would require urgent or immediate intervention. However, depending on the clinical circumstances, this intervention might only be limited to simple wound toilet and haemostasis, rather than a more comprehensive repair. There has also been a clear move (particularly in complex cases) toward wide surgical access, precise anatomical reduction and, when necessary, bone grafting—sometimes referred to as a "one-stop shop."

Unfortunately, comprehensive repair of extensive facial injuries, if undertaken too early in the multiply injured patient, could result in potentially very sick patients, or those with unrecognised injuries (notably spinal, chest, abdominal, and retroperitoneal), undergoing complex and lengthy surgery at a time when arguably, they would do better in intensive care. Prolonged immediate surgery in any physiologically

Table 2.1 Early total care and damage control

Early total care
Once resuscitated, take the patient immediately to theatre for immediate, complete, and definitive surgery
Damage control
Resuscitate and stabilise the patient haemodynamically. This may include urgent embolisation.
Minimal theatre time (1 h), to stop bleeding and prevent infection.
Transfer to the intensive care unit for continued care
Planned definitive repair later, when the patient is in a much better condition.

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compromised patient may further increase the risk of multiorgan failure.

However, if we simply leave all our patients for several weeks before we treat them, the development of late complications (notably respiratory and sepsis) may result in patients becoming too sick to undergo prolonged surgery. We may then have missed the opportunity of treating them altogether. Up to one third of all patients sustaining chest injuries develop pulmonary complications and sepsis. These are a particularly troublesome group when it comes to timing surgery. These risks significantly increase in the elderly or when four or more ribs are fractured. Surgery can also be technically more challenging when delayed, as the healing process is well underway. This often results in a hyperaemic surgical field, granulation tissue between the fractures, and a degree of soft tissue contraction. Consequently it becomes much harder to mobilise and precisely reduce the tissues, sometimes necessitating wider exposure and a longer procedure.

The optimal time to definitively repair facial fractures is therefore a delicate "balancing act" that needs to take into account all the patient's injuries and their physiological status. Blood loss is a key element to this. Significant haemorrhage sets off a potentially lethal chain reaction, starting with a "lethal triad" of acidosis, hypothermia, and coagulopathy. If this triad is not countered quickly, it can progress to multiorgan failure and death.

In those cases where facial injuries are relatively localised and low energy, surgery can often be deferred if necessary, for a short while with no significant effect on outcomes. Better outcomes may be possible with earlier or immediate repair, but this needs to be balanced against the patient's overall condition. Unfortunately, when facial injuries and injuries below the collar bones occur in the same patient, what we would ideally like to do may be compromised by injuries elsewhere and we may have no choice but to modify our treatment plan. Even potential injuries can significantly alter our management until they are ruled out ("can I turn the head?", "can the patient see?"). In such cases rapid temporary reduction and stabilisation of mobile, bleeding fractures may still be required. This is effectively our equivalent of "damage control surgery."

When facial injuries occur in isolation, decision making is much simpler. Complicating injuries below the collar bones are not present. With mandibular fractures, it is generally considered that these should ideally be repaired as soon as possible. With such open fractures (i.e., those associated with an overlying laceration, or involvement of the periodontium), it is often assumed that the longer the delay in repair, the more likely it is that infection will occur. However, what is unclear from the literature is how much of a delay is clinically acceptable. Although some clinicians may feel that a delay of more than a few days may put patients at risk, a number of studies have failed to demonstrate a direct relationship between delays in repair and any increase in complication rates. Excessive fracture mobility, poor oral hygiene, and smoking are probably more likely to result in poor outcomes. If these can be minimised, safe delays may be possible. By and large, it appears that in the absence of airway problems, active bleeding and excessively mobile (and painful) fragments, most patients with mandibular fractures can be safely deferred until the next day, or even longer. General anaesthesia in itself can be risky and is best avoided late at night. When prolonged delay is anticipated, temporary support using a collar, bridle wire, and/or temporary intermaxillary fixation (IMF) are useful interim measures. Anecdotally, delays of several days are quite possible with no adverse incidents or outcomes. This of course is far from ideal but may be unavoidable.

Swelling is another important factor that can affect timing. Although this is often extensive following high-energy "panfacial" injuries, the amount of swelling that can develop in lower energy fractures can vary. When swelling is significant, many surgeons may elect to defer surgery until it has nearly resolved. This allows clinical examination (both preoperatively as well as during surgery), and the accurate placement of aesthetic incisions, notably around the eyelids. This approach, however, may commit the patient to two procedures if, for example, urgent repair of a coexisting mandibular fracture is required.

Timing of surgery can therefore be complicated and may not be as simple as we would like. All injuries (known and potential) together with the patient's overall clinical state need to be taken into account. A team approach is therefore essential in considering all these factors. The final decision of when to repair facial injuries is therefore made on a case-by-case basis (*see* Table 2.2). Usually there is no right or wrong time and a degree of variability is usually acceptable and often unavoidable, depending on local resources.

Table 2.2 When should we repair these injuries?

Is the patient stable or critically ill?
Do they have any other (nonfacial) injuries? What are the implications of these on outcomes?
Are all necessary investigations completed?
Is the neck "clear" or will it be cleared soon?
What is the patient's visual and neurological status? Will we be able to find out soon?
How swollen is the face?
What fractures do they have and how urgent is their repair?
Is this a combined case (notably with neurosurgeons and ophthalmology)?
Is there any wound contamination?
How long will surgery take? What needs to be done?
Do I need any nonstock items ordered?
Which list should I use?

2.2 Airway Considerations in Anaesthesia

2.2.1 Submental Intubation

On occasion, surgery is required in patients in whom nasal intubation is not possible (or is contraindicated) but there is also a need for IMF during surgery (*see* Fig. 2.1).

In those cases where there are edentulous spaces present, it may be possible to intubate the patient orally and achieve IMF by passing the endotracheal tube out through a space. However, if all the teeth are present or the spaces are not big enough, this will not be possible. Whilst a tracheostomy is an obvious alternative, this may not be desirable, particularly if it is not required following surgery. Extraction of one or more teeth to create an edentulous space may also be undertaken, but this may be difficult to justify if they are in a good condition.

Another alternative is the use of submental intubation. In essence this is an oral endotracheal (ET) tube that exits the patient through the floor of the mouth and neck, rather than out through the oral cavity (*see* Fig. 2.2).

Choice of tube is important. This is required to undergo a sharp bend and therefore must not kink. For this reason, reinforced tubes are often used (so make sure your anaesthesia colleagues know in advance) (*see* Figs. 2.3 and 2.4).

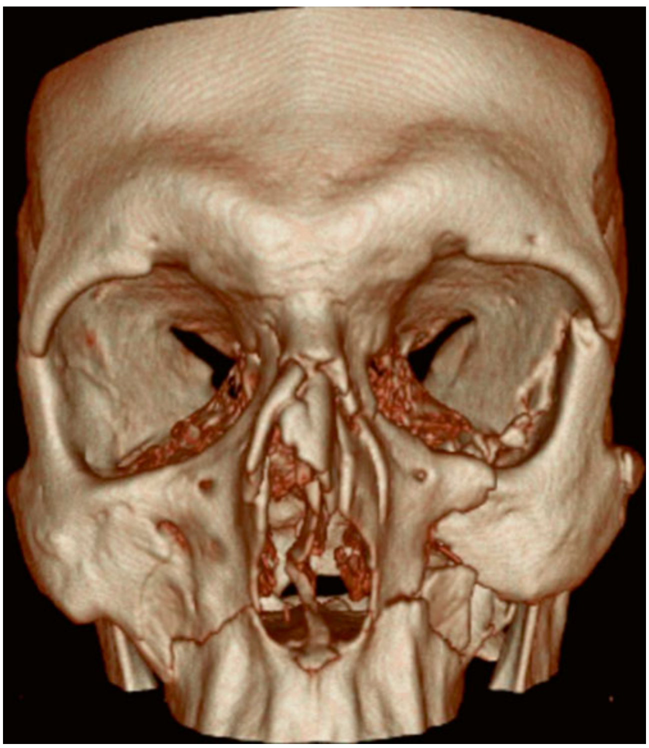

Fig. 2.1 Multiple facial fractures (nasal, LeFort, and left zygoma), requiring operative IMF and full access to the nose. A good case for submental intubation

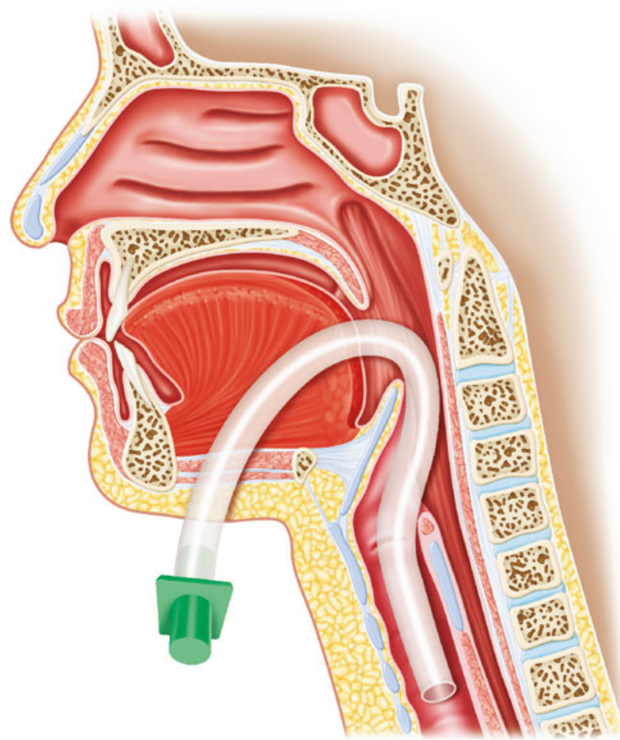

Fig. 2.2 Submental intubation. The endotracheal tube exits through the floor of mouth and neck. This allows IMF in the fully dentate patient

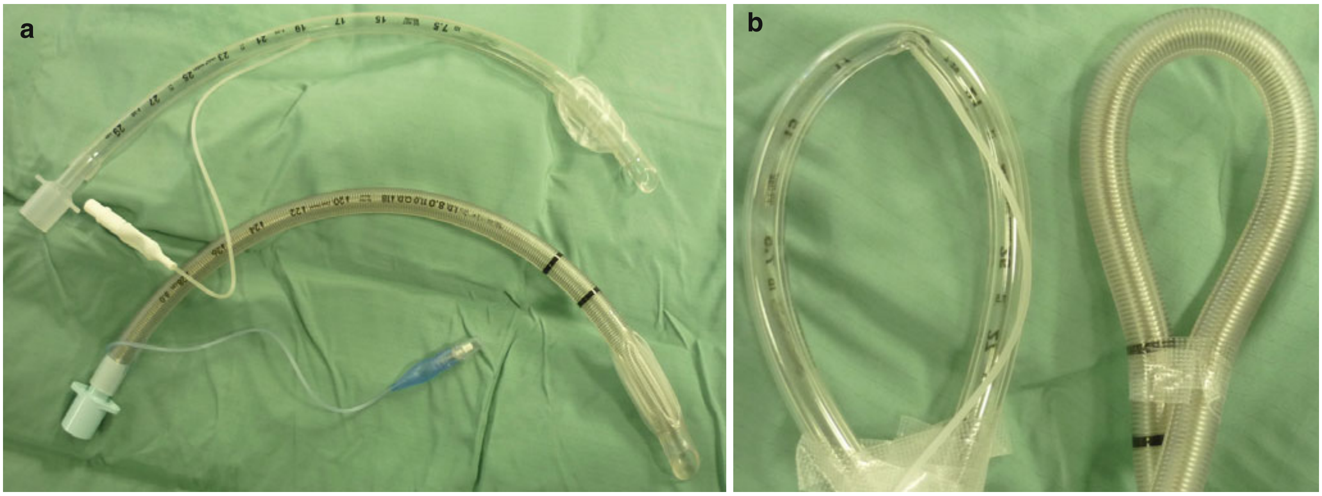

Fig. 2.3 (**a**, **b**) A standard ET tube and reinforced tube. Reinforced tubes do not kink when sharply bent. Submental intubation requires this

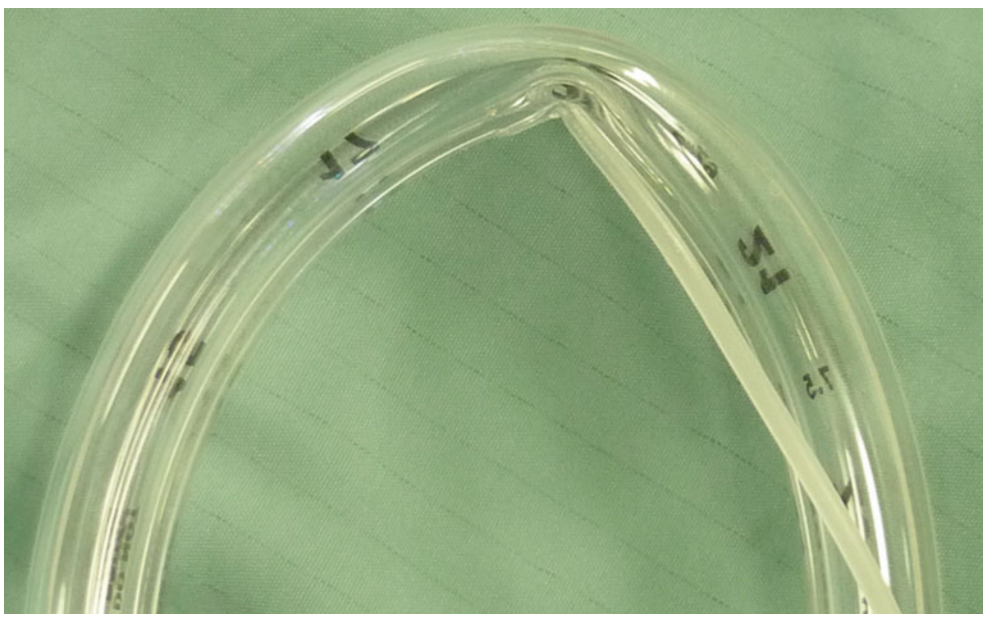

Fig. 2.4 Close up view of standard ET tube, showing partial blockage due to kinking

2.2.2 Submental Exposure

Case 1

A full-thickness skin incision, large enough to allow the passage of two retractors and the tube (approximately 2 cm in length) is made in a suitable skin crease in the submental region. Blunt midline dissection then proceeds towards the midline of the floor of the mouth, passing through the mylohyoid muscle and between the digastric muscles (*see* Fig. 2.5).

Fig. 2.5 Case 1. A midline skin incision (**a**) and initial dissection (**b**). (**c**) Blunt dissection continues through the mylohyoid muscle, between the anterior bellies of the digastric muscle

A second midline incision is then made in the mucosa of the floor of the mouth, paying particular attention not to damage the submandibular ducts. Further blunt dissection then completes a tunnel, passing through the floor of the mouth and out through the submental incision. This tunnel is gradually enlarged by gentle stretching until it is large enough to comfortably allow passage of the surgeon's index finger. For those not familiar with this technique two retractors are then placed either side of the tunnel to keep it open. A large curved clip is then passed through the tunnel from the neck into the floor of the mouth. With the patient fully oxygenated, the endotracheal tube is temporarily disconnected from the anaesthetic circuit and its end is grasped by the curved clip. The end is then gently fed through the tunnel, taking care not to dislodge the distal end of the tube in the process. So long as the tunnel is of adequate size, this part of the procedure should only take 10–20 s. The anaesthetic circuit is then reconnected and ventilation confirmed (*see* Figs. 2.6, 2.7, 2.8, 2.9 and 2.10).

The tube is then secured to the neck and surgery can proceed with full exposure of the face, unhindered by any anaesthetic equipment. At the end of the surgery the process is reversed so that the tube now passes out through the mouth.

A variant of this approach is to bring the tube out through a more laterally sited tunnel and skin incision. This allows the tube to lie alongside the tongue in the lateral floor of the mouth. This is a matter of personal preference (*see* Figs. 2.11 and 2.12).

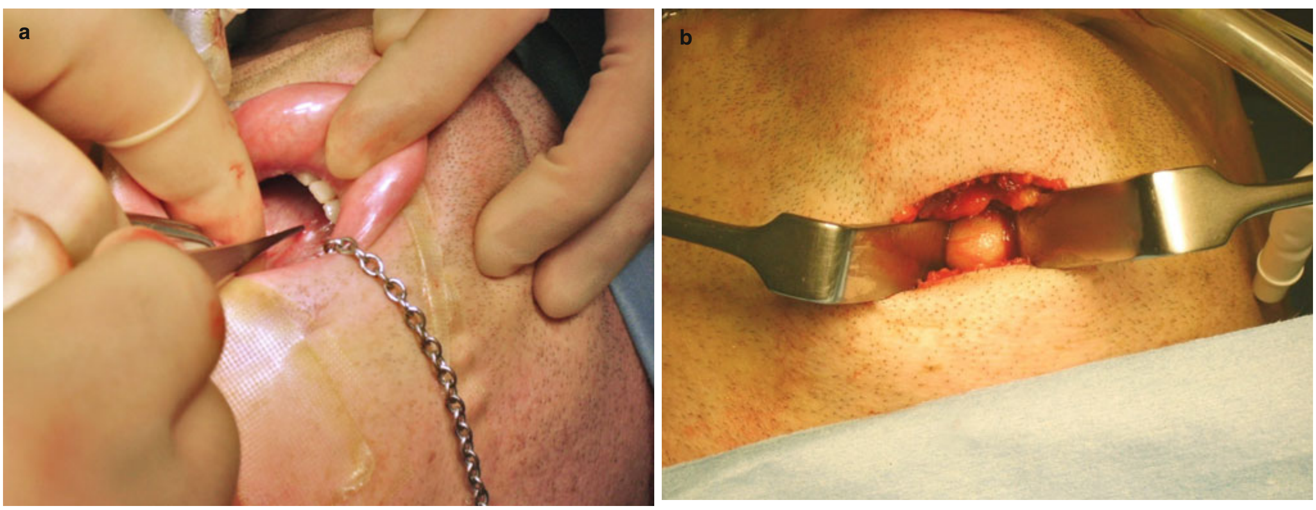

Fig. 2.6 Case 1 continued. The intraoral incision is carefully placed between the submandibular ducts openings (**a**). Blunt dissection continues to meet the external dissection (tip of surgeon's finger is seen in **b**)

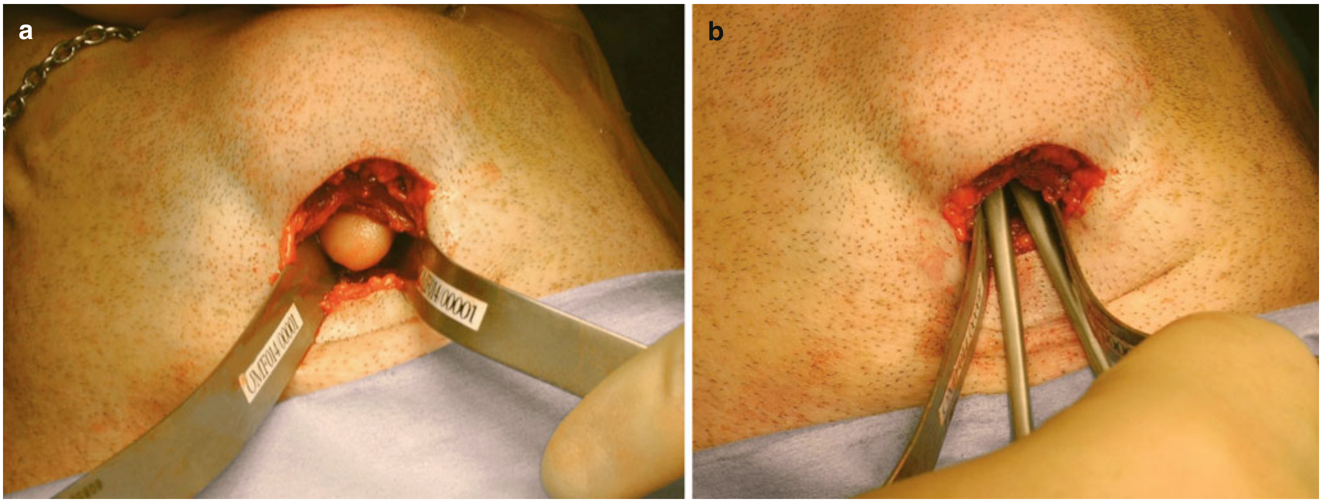

Fig. 2.7 Case 1 continued. The tunnel is gradually enlarged and two malleable retractors are placed either side to prevent it from collapsing in on itself (**a**). A large curved clip is then passed through the tunnel (**b**)

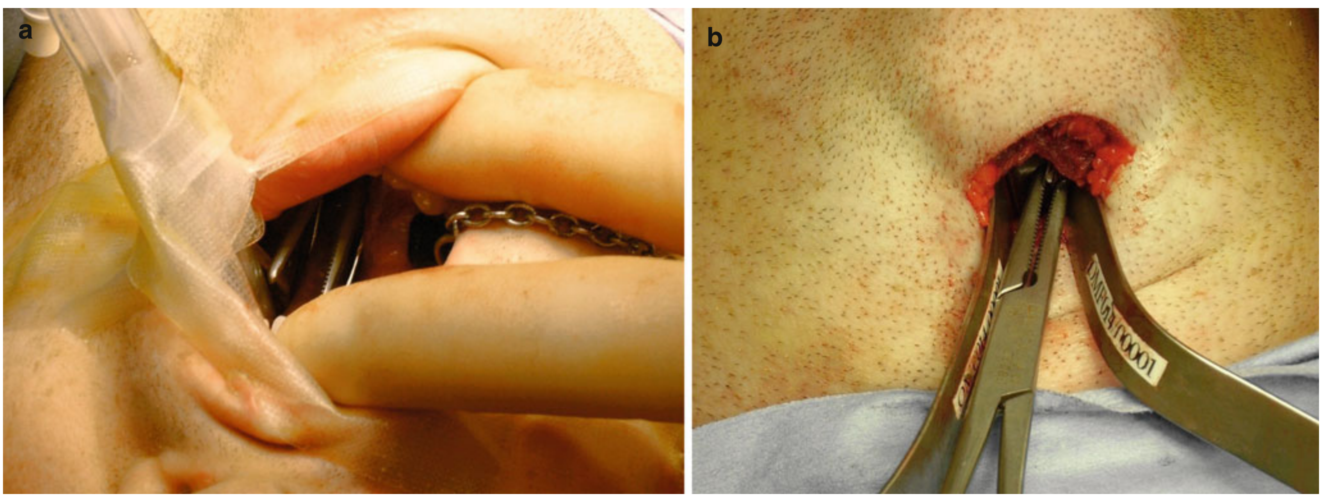

Fig. 2.8 Case 1 continued. The clip must be clearly seen in the mouth (**a**). The ET tube is disconnected and grasped by the clip, then slowly passed through the tunnel (**b**)

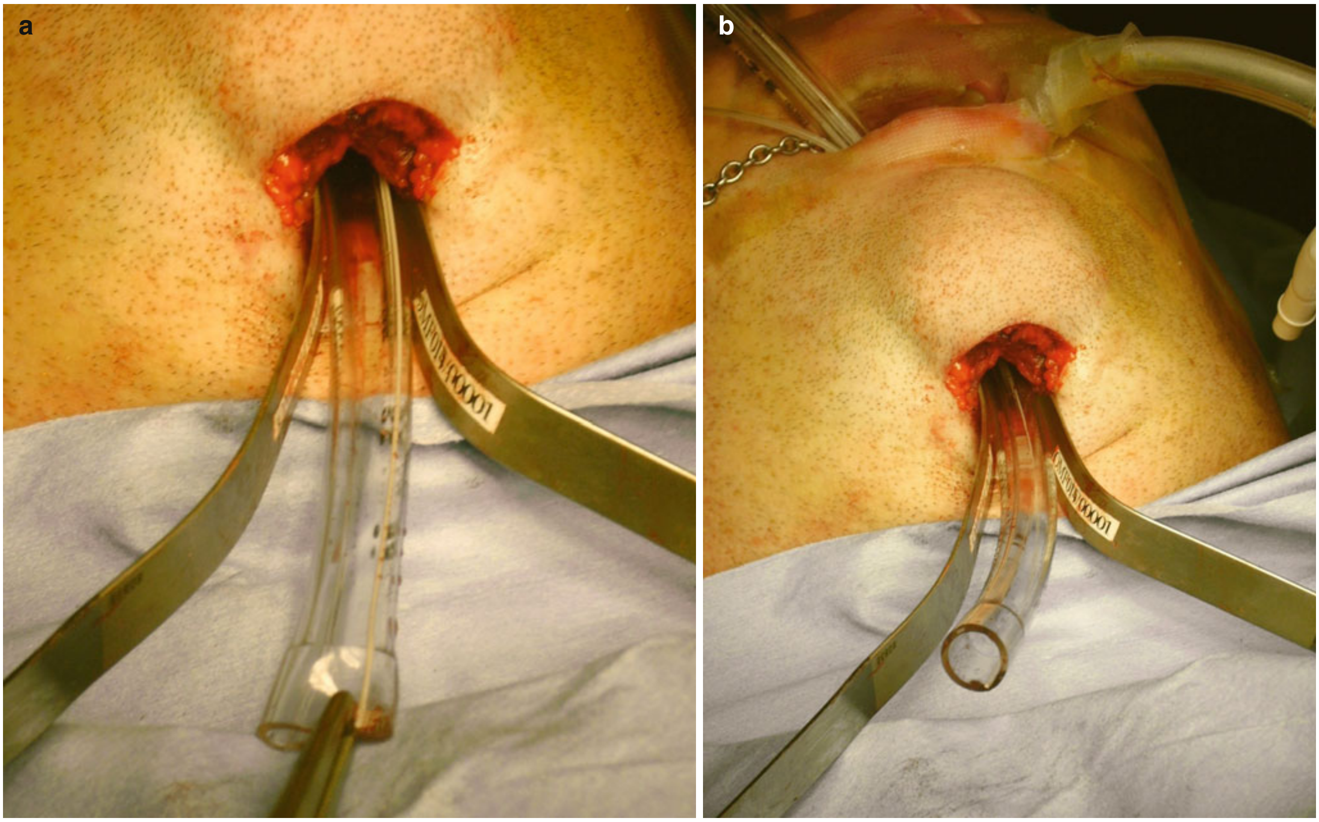

Fig. 2.9 Case 1 continued. ET tube successfully passed (**a**, **b**)

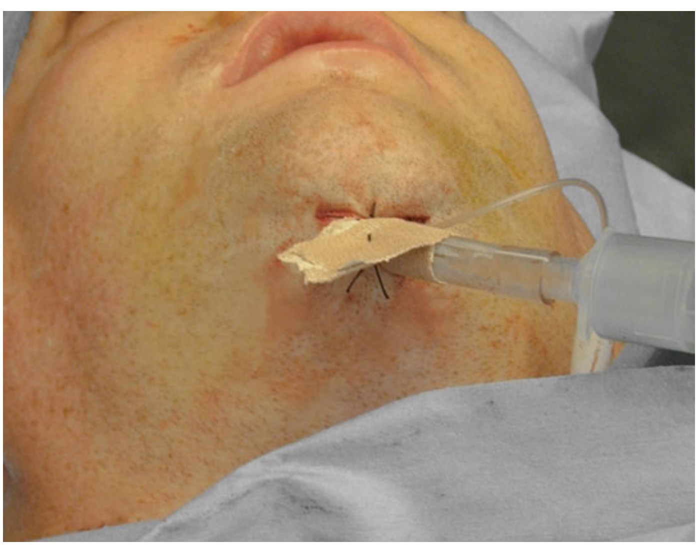

Fig. 2.10 Case 1 completed. Anaesthetic circuit reconnected

Case 2

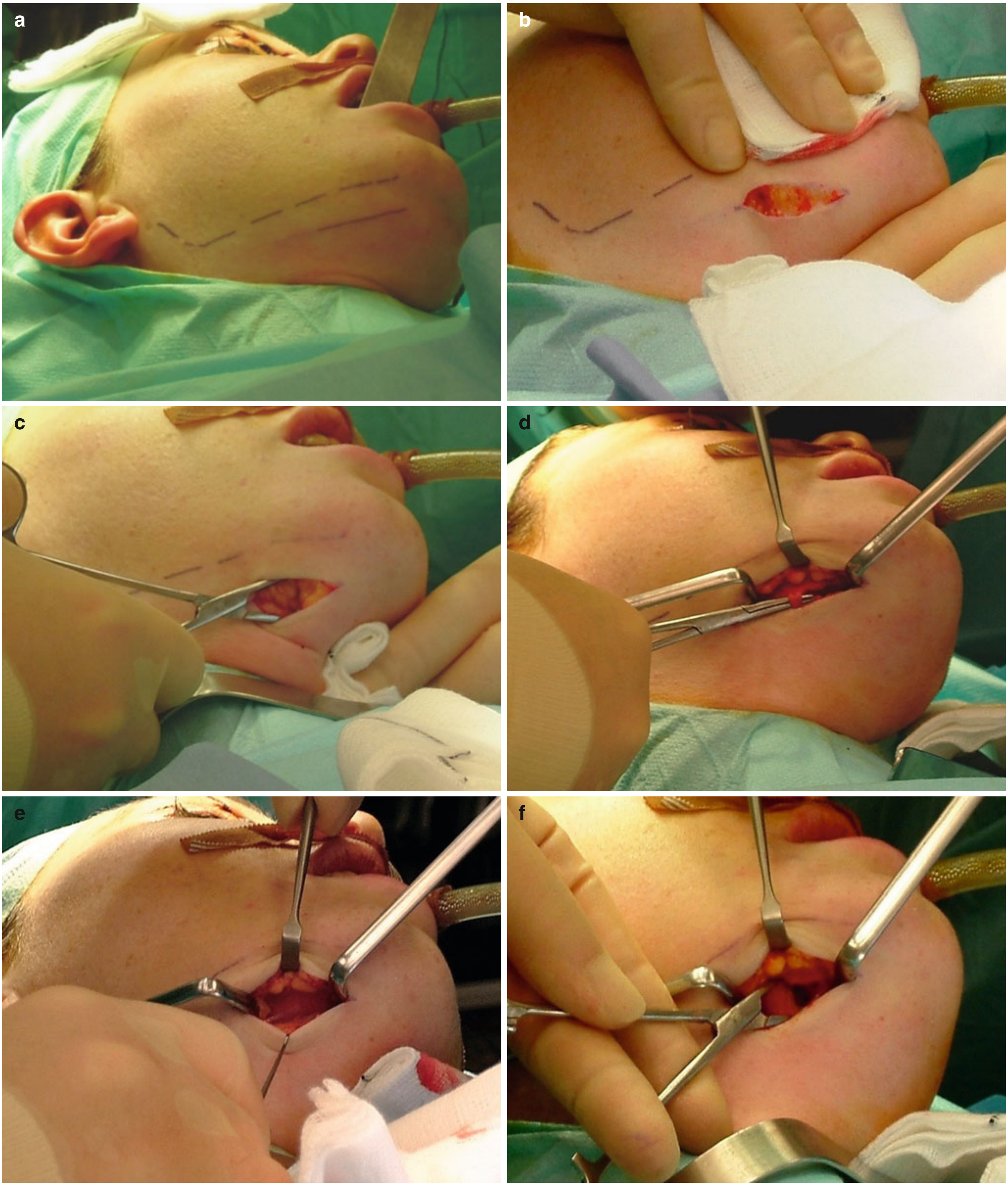

Fig. 2.11 Case 2. (**a**–**h**) In this case, a slightly more lateral approach was taken. Depending on the size of the patient there may be more tissues to dissect through. The facial artery and vein may also be encountered (**d**). These can be retracted or divided. Otherwise the steps taken are essentially the same as those in Case 1. With practice, smaller incisions may be possible

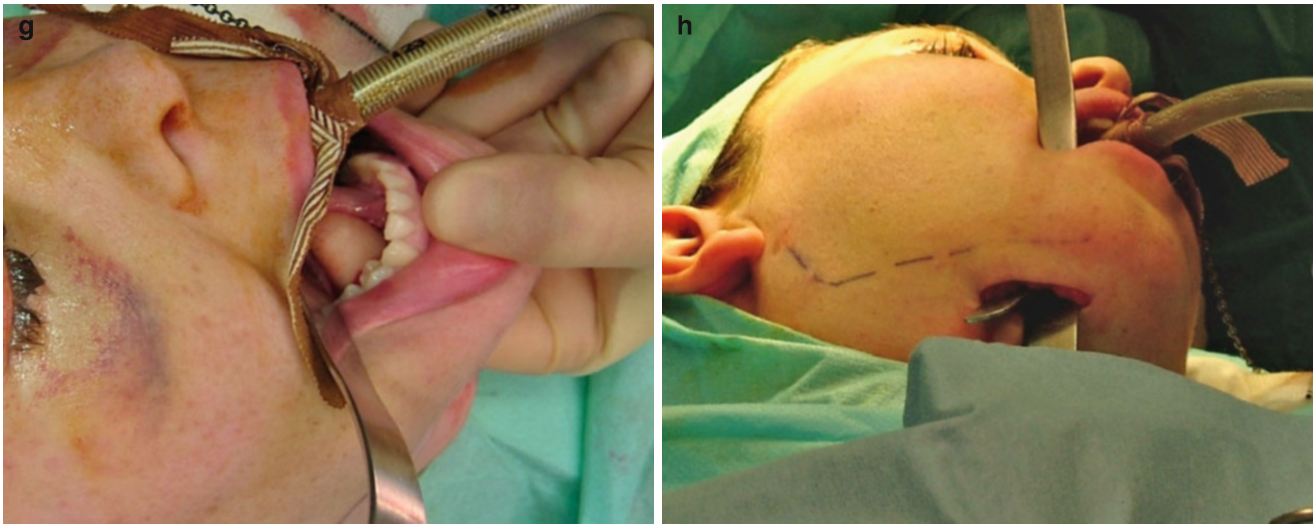

Fig. 2.11 (continued)

Case 3

Submental intubation requires careful forethought, particularly with regards to choice of endotracheal tube. When placed, the tube often undergoes a sharp bend and can therefore kink, if it is not of adequate rigidity. In some tubes the connectors are fixed to the end and cannot be removed. Flanges on the connectors can catch in the soft tissues of the tunnel.

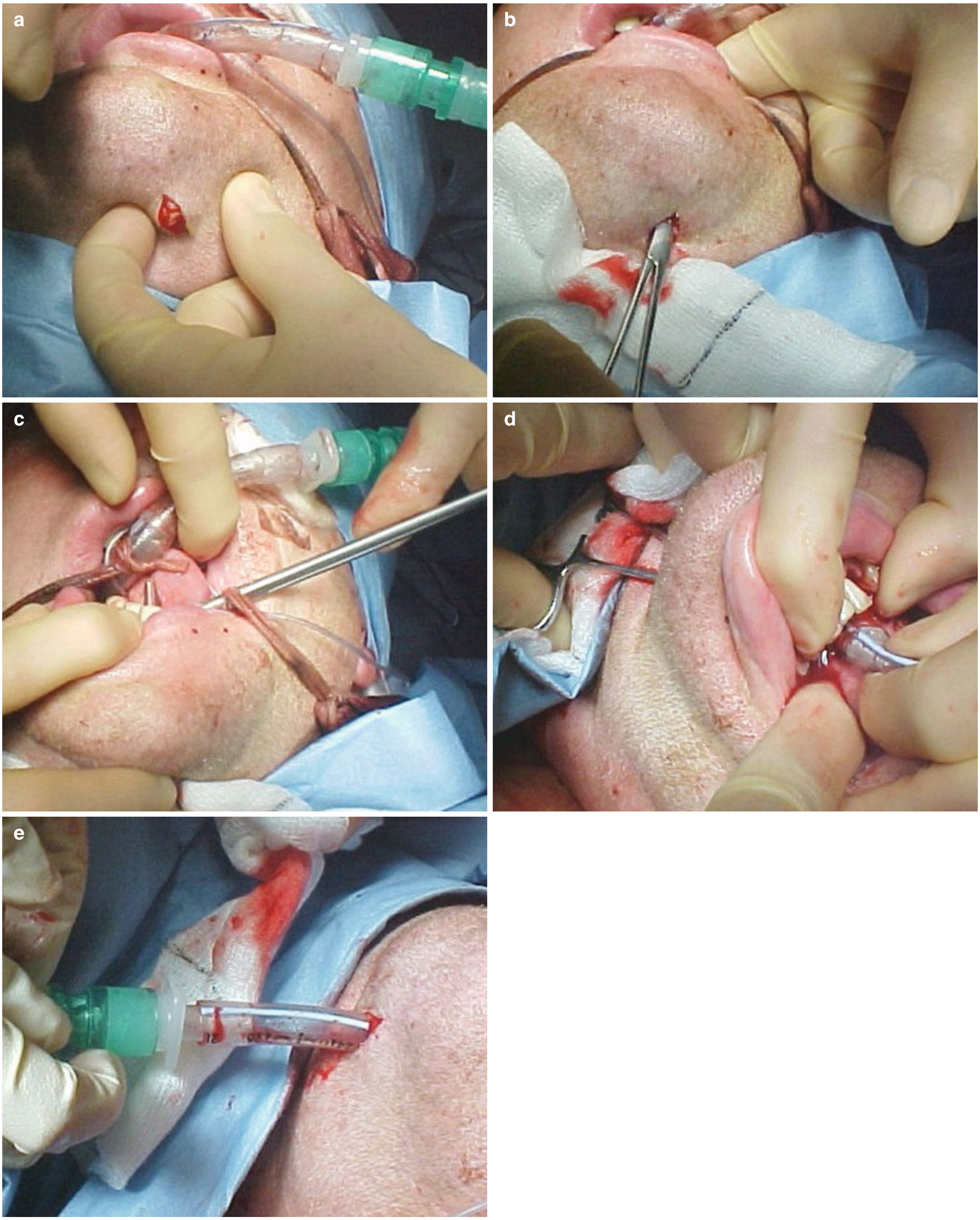

Fig. 2.12 Case 3. Successful submental intubation though a smaller stab incision (**a**–**e**; not to be recommended to the inexperienced)

2.3 Tracheostomy

With the development of percutaneous tracheostomy and its established record of safety and speed, the need to carry out surgical tracheostomies has been greatly reduced. In many centers today, open tracheostomy is usually reserved for patients in whom the anatomy is distorted or uncertain, or where the expertise for percutaneous techniques is not available. Nevertheless, open tracheostomy remains an important technique, which is still often required. Whereas the percutaneous method employs the Seldinger technique to sequentially dilate an opening in the trachea and overlying soft tissues (*see* Figs. 2.13–2.22), surgical tracheostomy requires direct exposure of the trachea and fenestration of its anterior surface. A number of variants in this procedure are well known.

2.3.1 Percutaneous Tracheostomy

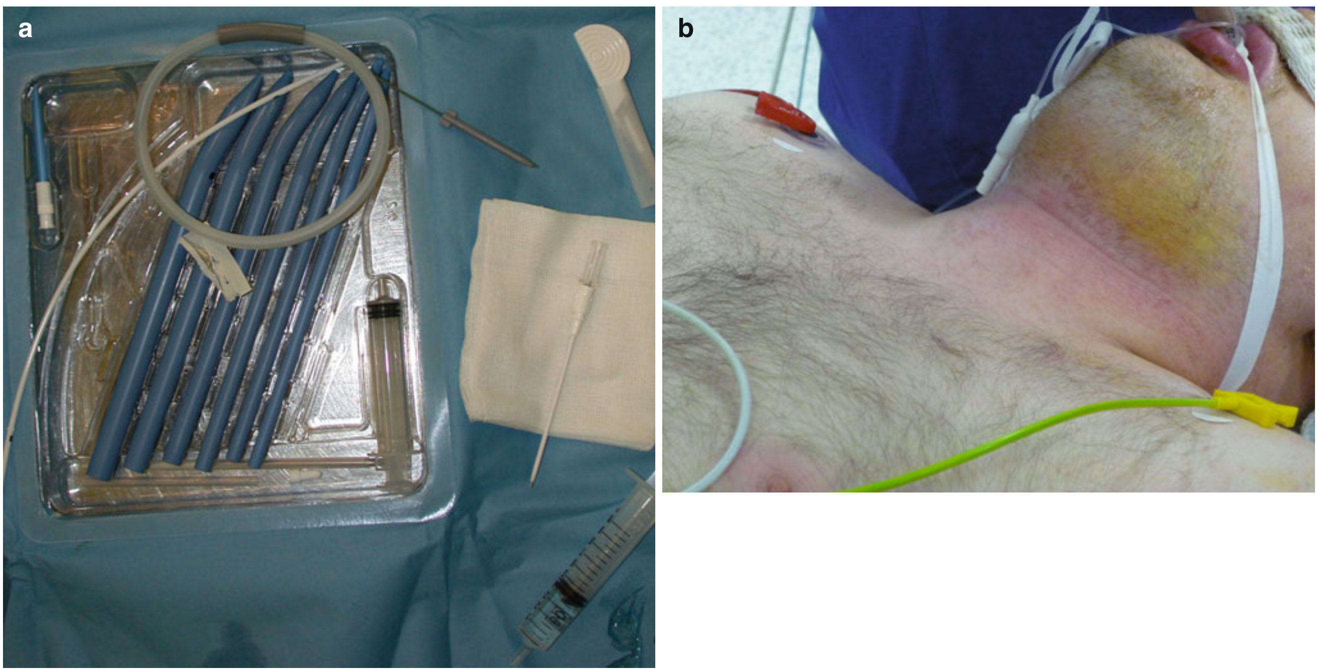

Fig. 2.13 Percutaneous tracheostomy kit (**a**) and initial patient position (**b**). Patient has already been anaesthetised and intubated

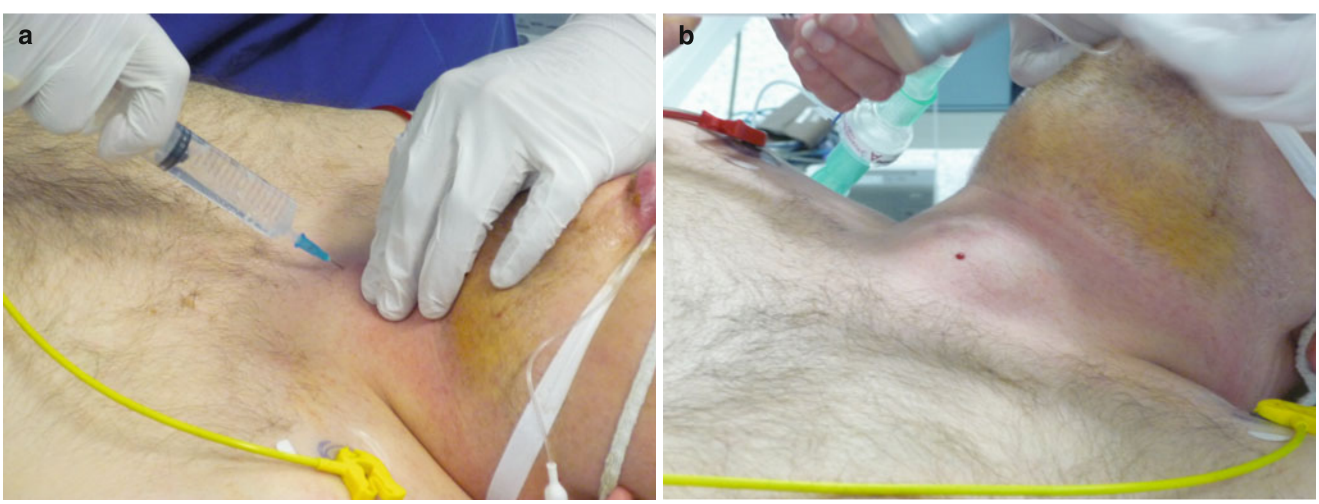

Fig. 2.14 Local anaesthetic containing adrenaline is infiltrated (**a**). This is to minimise bleeding (**b**)

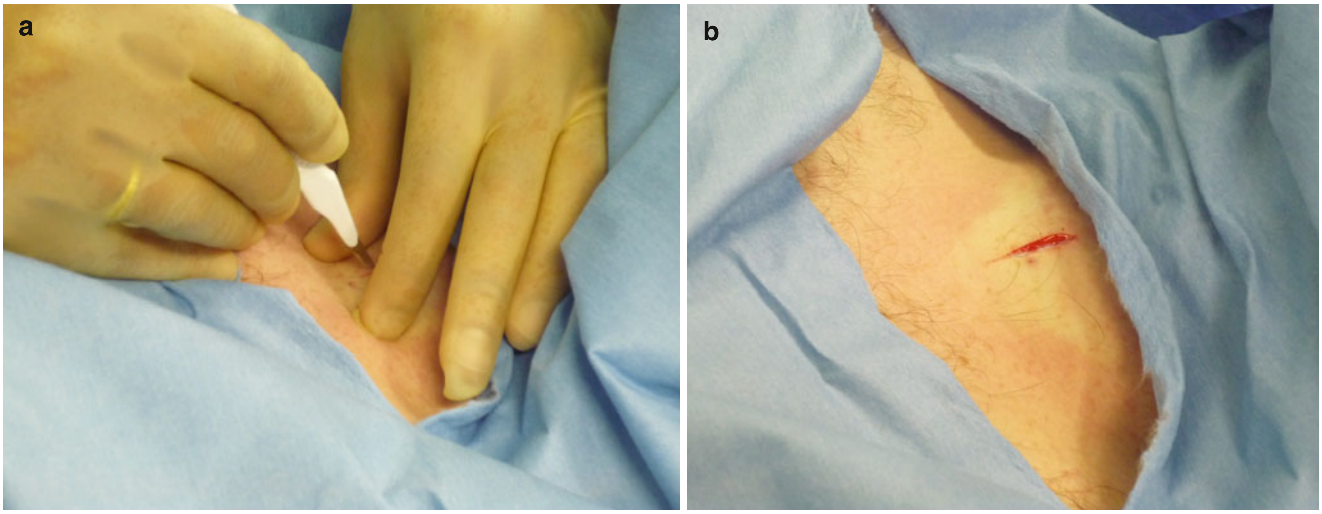

Fig. 2.15 A small incision is made in the skin (about 1 cm) (**a**, **b**)

Fig. 2.16 A fibreoptic camera is then passed through the ET tube, exiting out the end to visualise the tracheal lumen

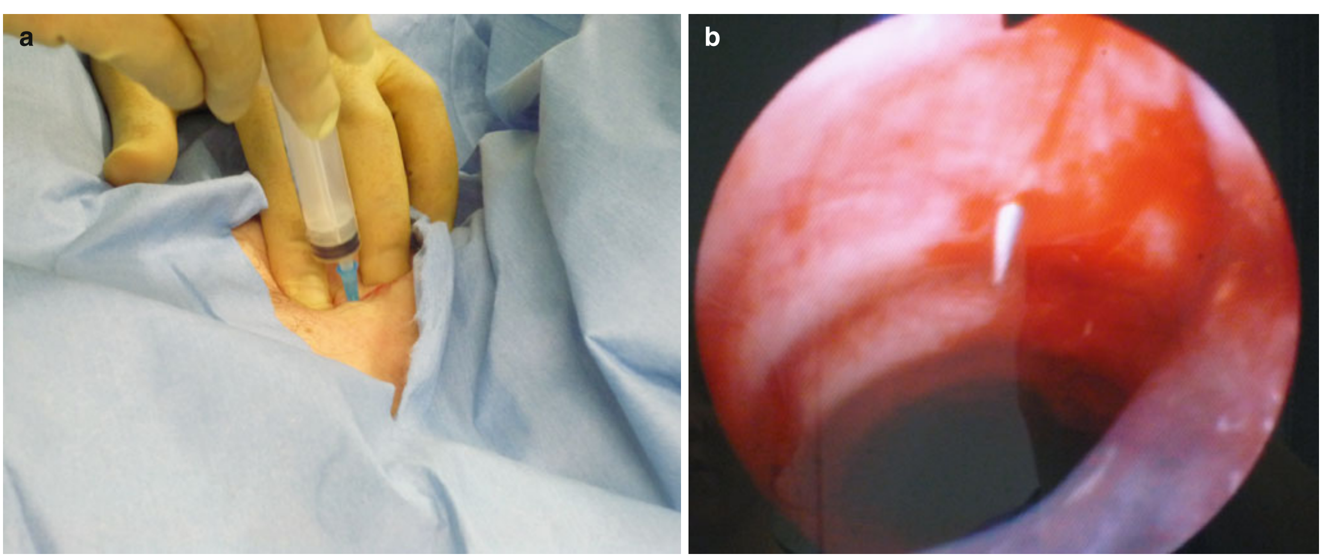

Fig. 2.17 A needle is passed through the stab incision down to the trachea (**a**). It is then slowly passed through the tracheal wall into the lumen, at approximately the level of the second and third rings. Verification of its entry into the trachea requires direct visualisation (fibreoptically) and aspiration of air (and anaesthetic gases) (**b**)

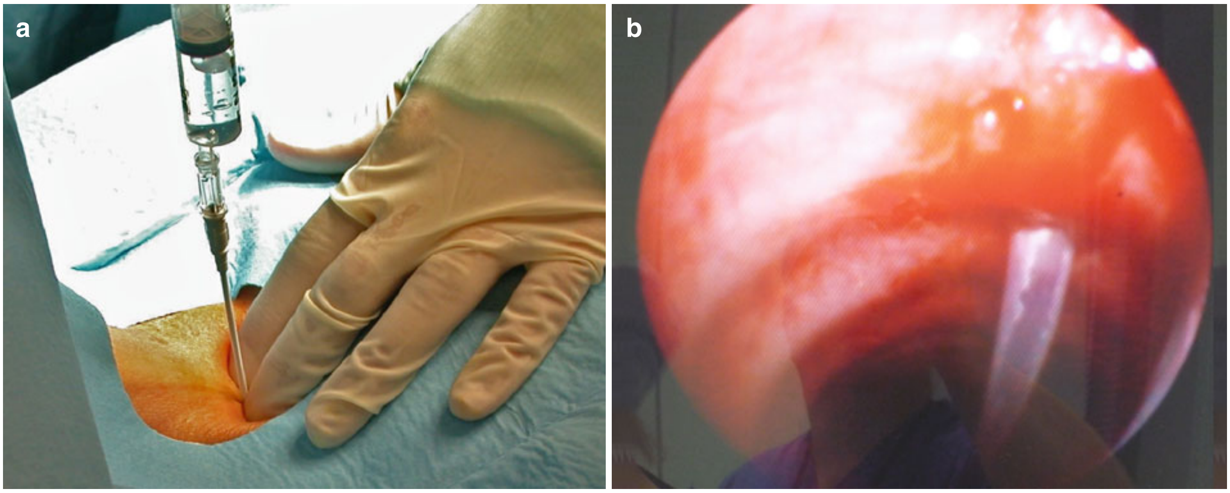

Fig. 2.18 The procedure is repeated using the larger needle and sheath (plastic cannula) supplied by the kit (**a**). Once the needle and sheath are confirmed to be in the tracheal lumen, the needle is removed, leaving the sheath in situ (**b**)

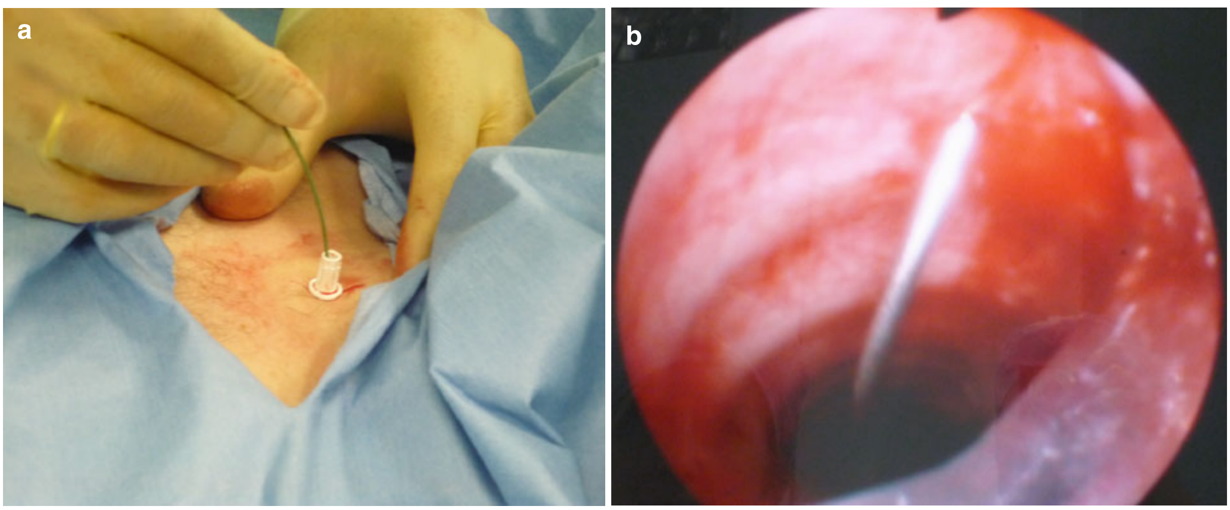

Fig. 2.19 A guidewire is then passed through the sheath (**a**). This is passed distally along the tracheal lumen under fibreoptic visualisation (**b**). Retention of this wire in the lumen is essential during serial dilation

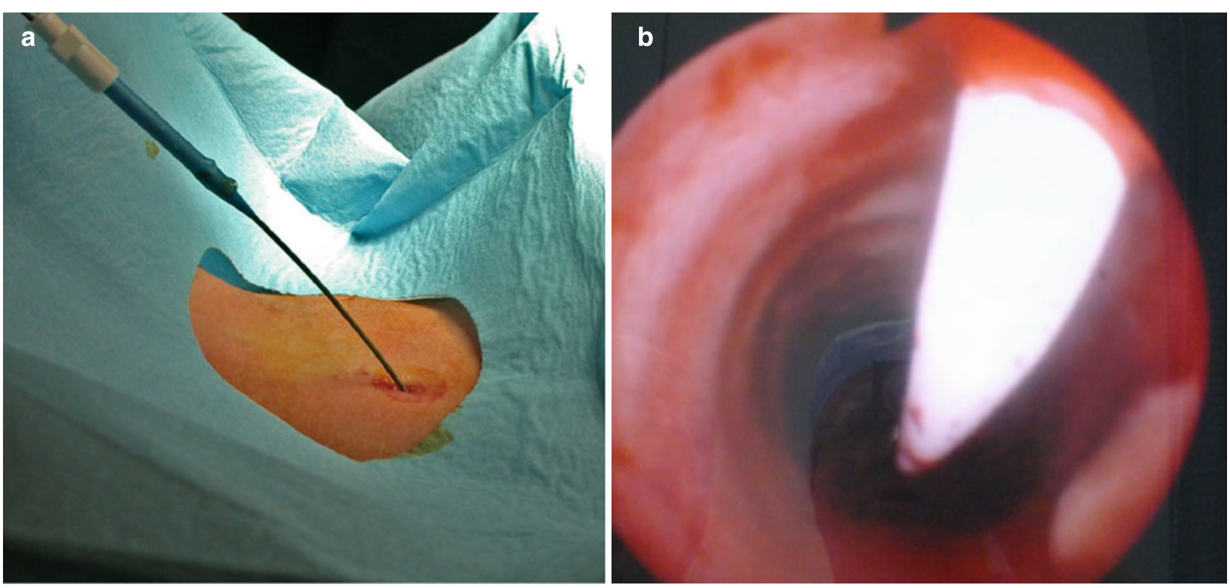

Fig. 2.20 Using the dilators (starting with the smallest diameter), the tract is gradually dilated (**a**). The dilators have a central bore to enable them to be passed over the guidewire. This ensures they pass into the tracheal lumen and are not deflected around the trachea (**b**). This technique therefore relies on the natural elasticity of all the tissues, including the trachea. In elderly patients it may be difficult to perform if the tracheal rings are heavily calcified

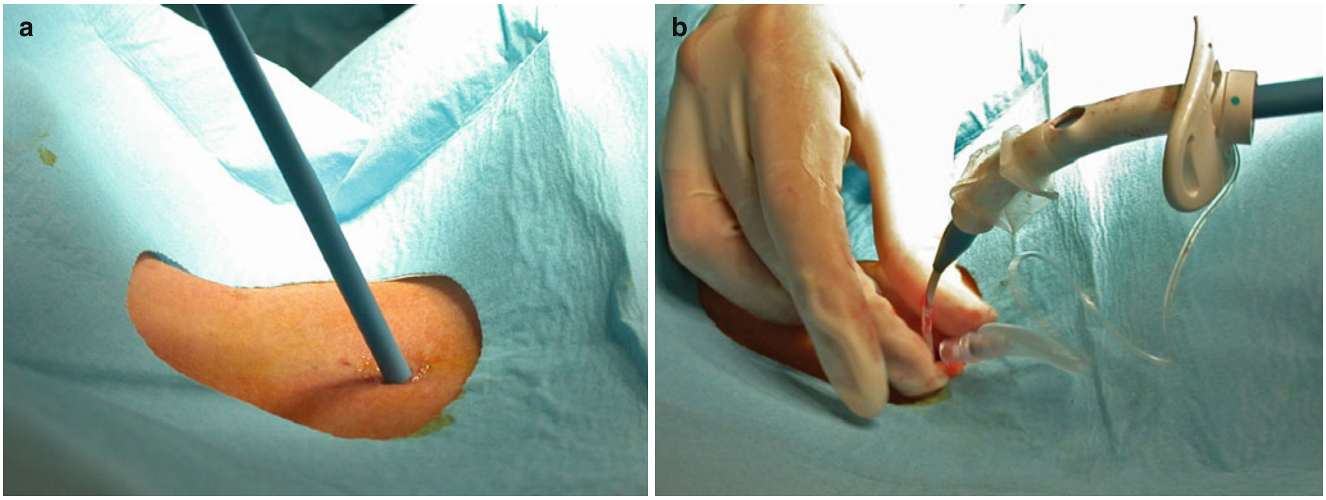

Fig. 2.21 The tunnel is serially dilated until large enough to pass the tracheostomy tube (**a**). Using the largest dilator as a guide, this is then passed and secured. The guidewire can then be withdrawn (**b**)

Fig. 2.22 The tracheostomy tube is then secured

Table 2.3 Helpful points in tracheostomy

This is an elective procedure: take your time
Check the tracheostomy tube before you start: is the cuff intact?
Give yourself adequate access
Ensure haemostasis as you proceed and before you fenestrate the trachea
Stay in the midline: care with retraction. Regularly palpate the surgical bed to maintain spatial orientation with respect to the trachea.
Tell the anaesthetist when you are ready to fenestrate the trachea; they need to prepare as well.
Elderly patients may have partially ossified tracheal rings. These can be very hard to divide.
Ignition of anaesthetic gases and oxygen has been reported, resulting in airway combustion and death of the patient (now unlikely with newer gases)

2.3.2 Open (Surgical) Tracheostomy

When performing an elective open tracheostomy, it is traditionally taught that sandbags should be placed under the shoulder blades and the neck fully extended, in order to improve access to the trachea. Unfortunately in a trauma setting this may not be possible, particularly if there are any concerns regarding the integrity of the cervical spine. Furthermore, if the tracheostomy tube is secured with the neck fully extended, it may risk displacement when the neck is returned to the neutral position. For these reasons, surgical tracheostomy may be best done with the neck in the neutral position. By following a number of simple principles, carrying out a tracheostomy should be relatively straightforward (*see* Table 2.3).

The crucial time during tracheostomy is when the trachea is fenestrated. Until then there should be plenty of time and no need to rush. The "point of no return" is not reached until this opening is made. However, once the tracheal wall has been breached, ventilation can become a problem, particularly if the cuff on the endotracheal tube has been ruptured in the process. With care, rupture should rarely occur, as it should be possible to open the trachea without popping the cuff. If the trachea is fenestrated above an intact cuff, then ventilation can proceed unhindered while bleeding from the opening is stopped. As with all surgical procedures, know your anatomy and check your equipment before you start (*see* Figs. 2.23 and 2.24).

Landmarks are often drawn on the skin prior to surgery as an aid to dissection. The key landmarks are (from top to bottom [*see* Fig. 2.25]):

- Adam's apple
- Cricoid cartilage
- Sternal notch
- The midline

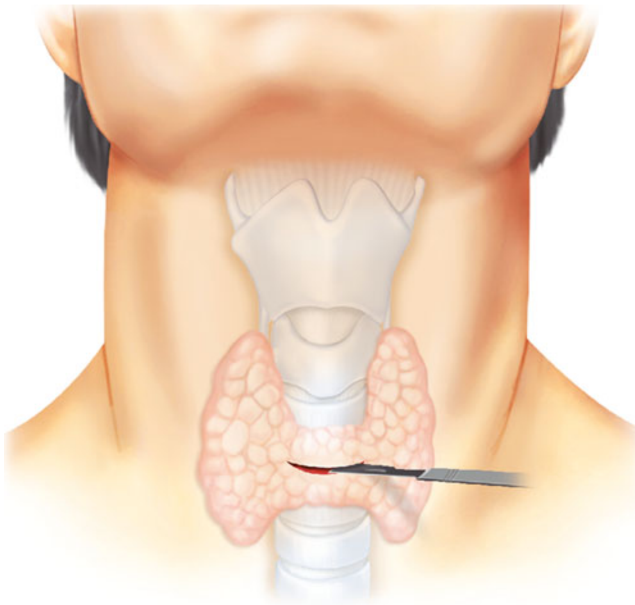

Fig. 2.23 Surgical anatomy in tracheostomy. Note the thyroid isthmus. This is commonly encountered and is highly vascular

Fig. 2.24 A presurgical check of the cuff and balloon is advised. You do not want to find there is a problem with it halfway through the operation

A horizontal full-thickness skin incision is made, approximately midway between the cricoid ring and the sternal notch. Some surgeons prefer to use a vertical midline incision. Cutting diathermy may be used to make the incision, but care is required as the anterior jugular vein may be encountered in the superficial fat (*see* Figs. 2.26, 2.27 and 2.28).

Blunt midline dissection is then performed, heading toward the trachea (after ensuring that the trachea is in the midline). The strap muscles are separated using retractors. Retraction technique is important during this stage and it is important that one assistant does not retract harder than the other, thereby causing the dissection to drift off to the side. It is therefore sometimes helpful to occasionally remove all retractors and palpate the surgical bed, feeling the trachea and reorientating oneself in the process. The retractors are then gently replaced and retracted once more (*see* Figs. 2.29, 2.30 and 2.31).

The thyroid isthmus is often encountered during a tracheostomy. This can either be retracted upward or divided and is a matter of personal choice. Retraction is a simpler process, but theoretically this could cause problems later due to pressure necrosis and bleeding, if the isthmus drapes the tracheostomy tube. It could also obstruct the opening in the trachea if the tube falls out. Dividing the isthmus may provide better access, but it is crucial that haemostasis of its stumps is secured. This is a highly vascular structure. Division of the isthmus can be done with cutting diathermy. The two stumps are then gently dissected off the trachea and the ends oversown (*see* Figs. 2.32, 2.33 and 2.34).

The upper part of the trachea should now be visible at this stage. This is a good time to complete haemostasis. Temporarily removing all the retractors will uncover and expose any unrecognised bleeding points. Enough of the trachea needs to be exposed for an adequate sized fenestration. However, it is important not to dissect or cauterise around its lateral curvature too far. This could injure the recurrent laryngeal nerve (*see* Fig. 2.35).

A number of openings into the trachea have been described. Generally the preferred site is approximately at the level of the second and third tracheal rings, but this can vary depending on the length of the neck and other anatomical features. Some surgeons prefer to use a vertical slit, which is then dilated to accommodate the tracheostomy tube. This is reported to result in a lower incidence of complications once the tube has been removed. A second alternative is the Björk flap. This is essentially an upside-down U-shaped incision in the trachea resulting in a flap that can be sutured to the skin (*see* Fig. 2.36).

The principle behind the Björk flap is that if the tracheostomy tube falls out it should be easy to replace. However, if the flap becomes loose and mobile, it could theoretically flip into the lumen of the trachea and obstruct it.

The third alternative is to simply cut a hole in the anterior wall of the trachea as shown. Depending on the age of the patient, the cartilage rings of the trachea can sometimes be quite ossified and difficult to cut. A pointed blade is usually required to start off the incision, which is then completed with heavy or blunt-tipped scissors.

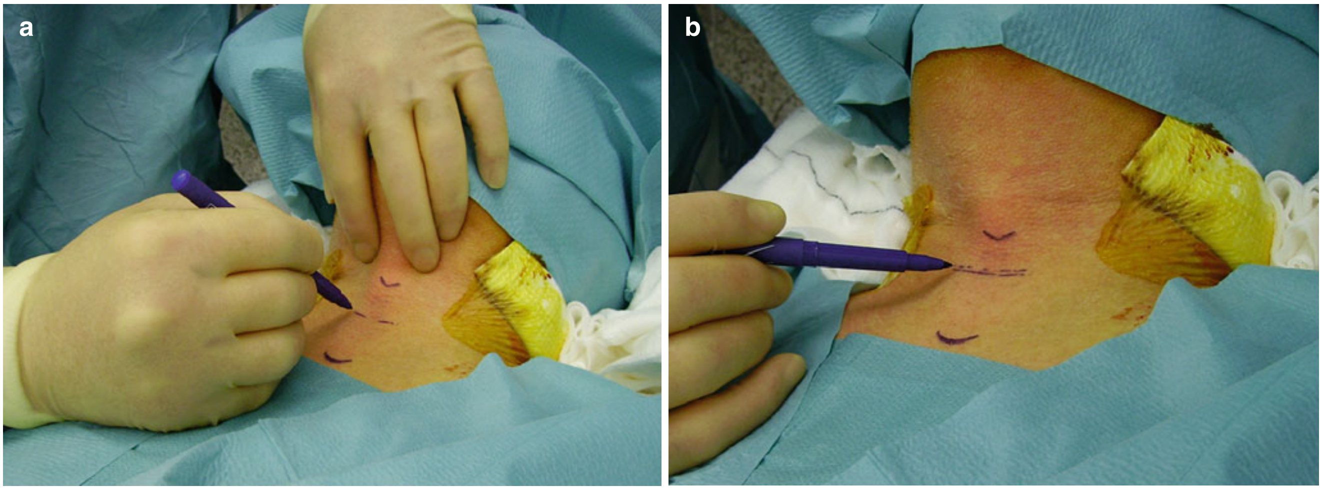

Fig. 2.25 Key sites are marked on the skin (**a**). Cricoid cartilage (uppermost) and sternal notch (lowermost), with the proposed skin incision approximately midway between the two (**b**). The patient's head is at the top

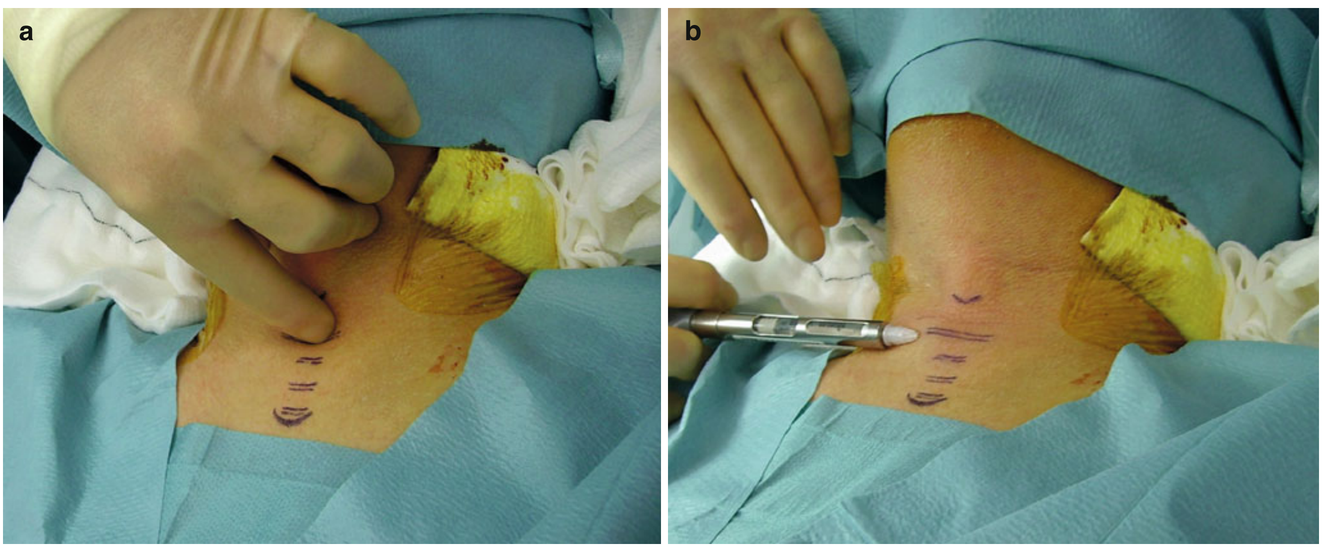

Fig. 2.26 The surgical bed is carefully palpated (**a**) and local anaesthesia with adrenaline injected (**b**)

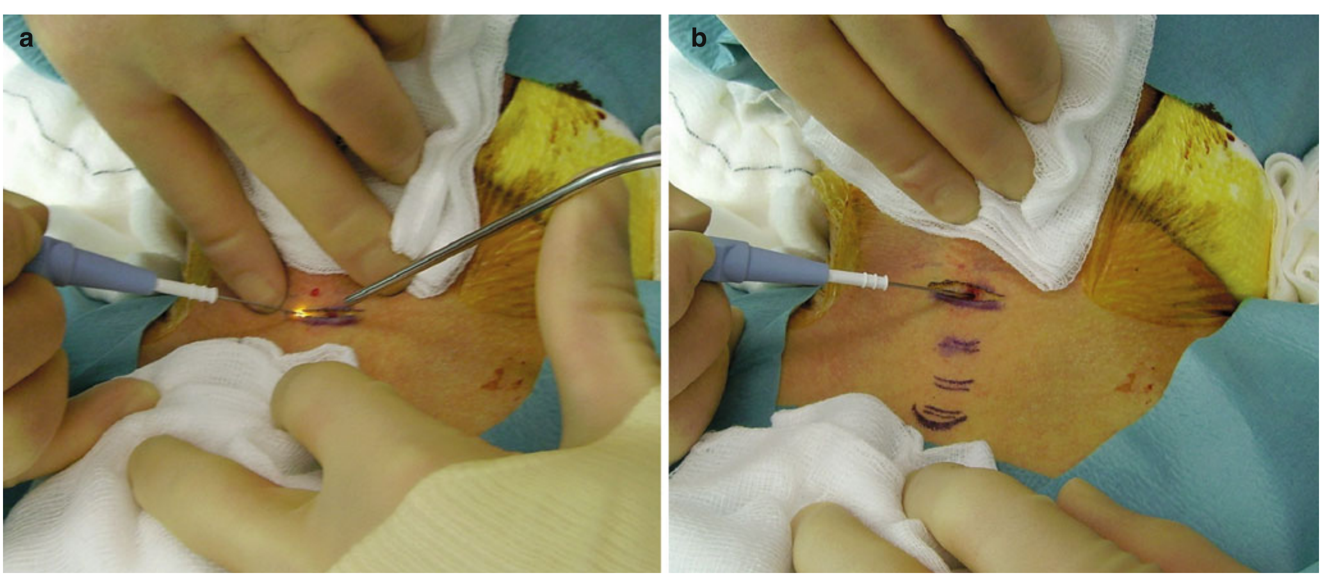

Fig. 2.27 Skin incision (**a**) with cutting diathermy (**b**)

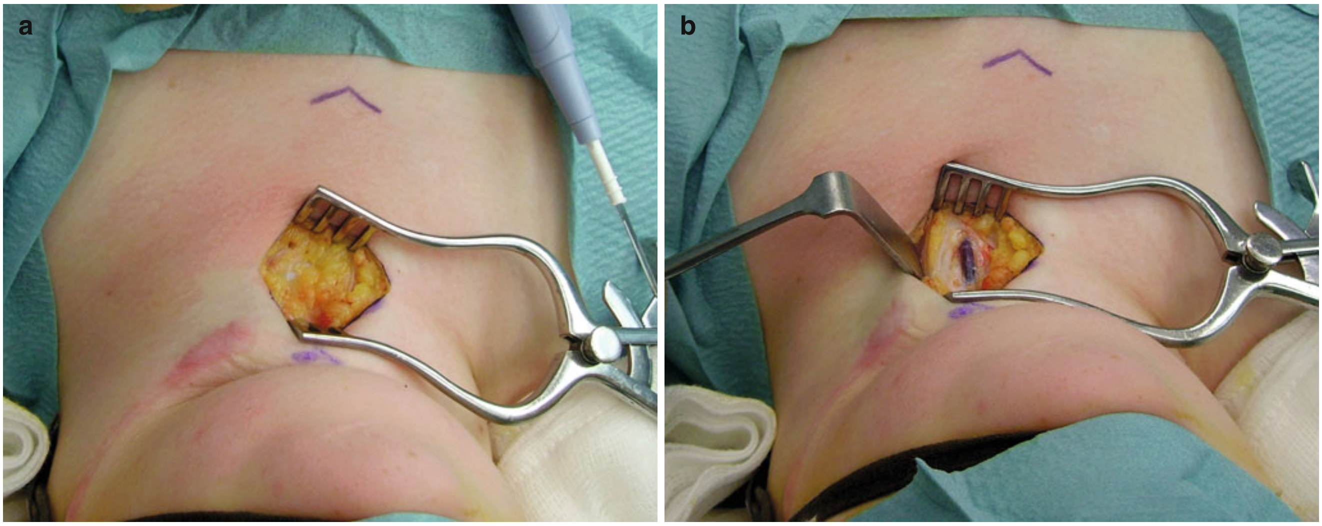

Fig. 2.28 In this different case, following initial skin incision (**a**) the anterior jugular vein is encountered in the midline (**b**). This often requires ligation (Patient's head is at the bottom. Viewed as if standing at the head of the table)

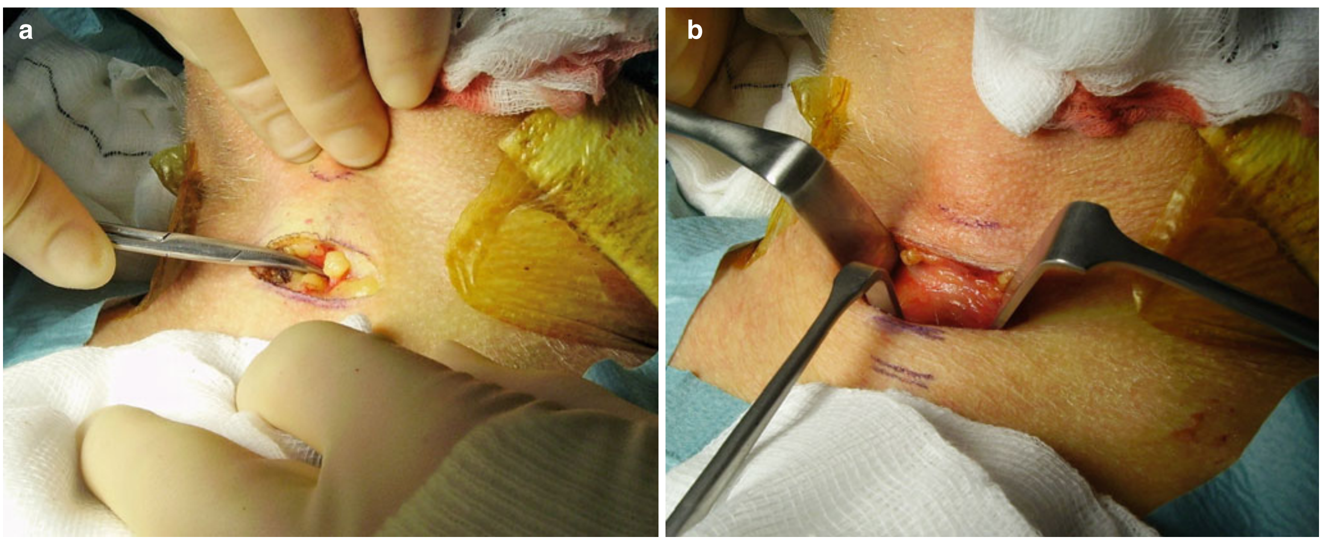

Fig. 2.29 Blunt dissection continues (**a**) remaining always in the midline (**b**). Patient's head is uppermost

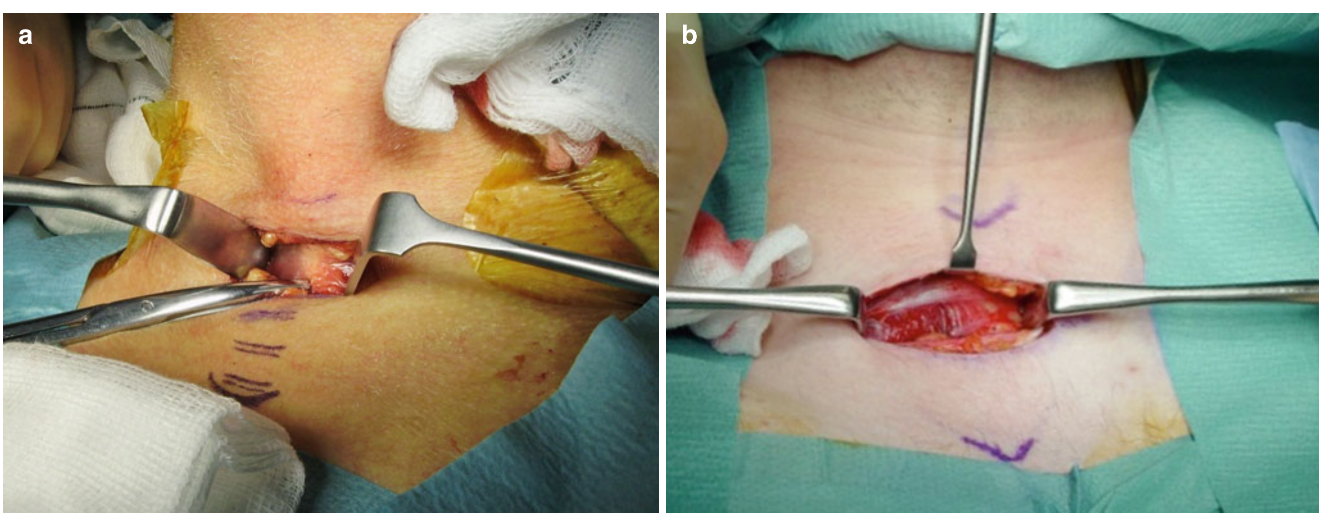

Fig. 2.30 The strap muscles are gently retracted laterally (**a**) as dissection deepens toward the trachea (**b**)

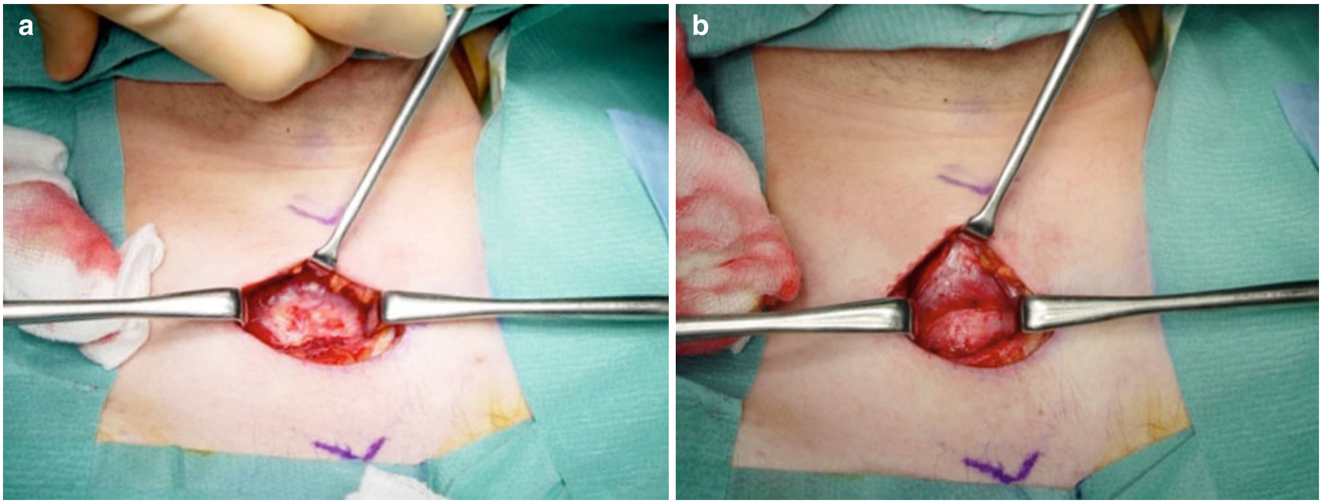

Fig. 2.31 In this case, the trachea is quickly exposed without encountering the thyroid isthmus (**a**). However, gentle retraction of the upper skin flap superiorly exposes it (**b**). Patient's head is uppermost

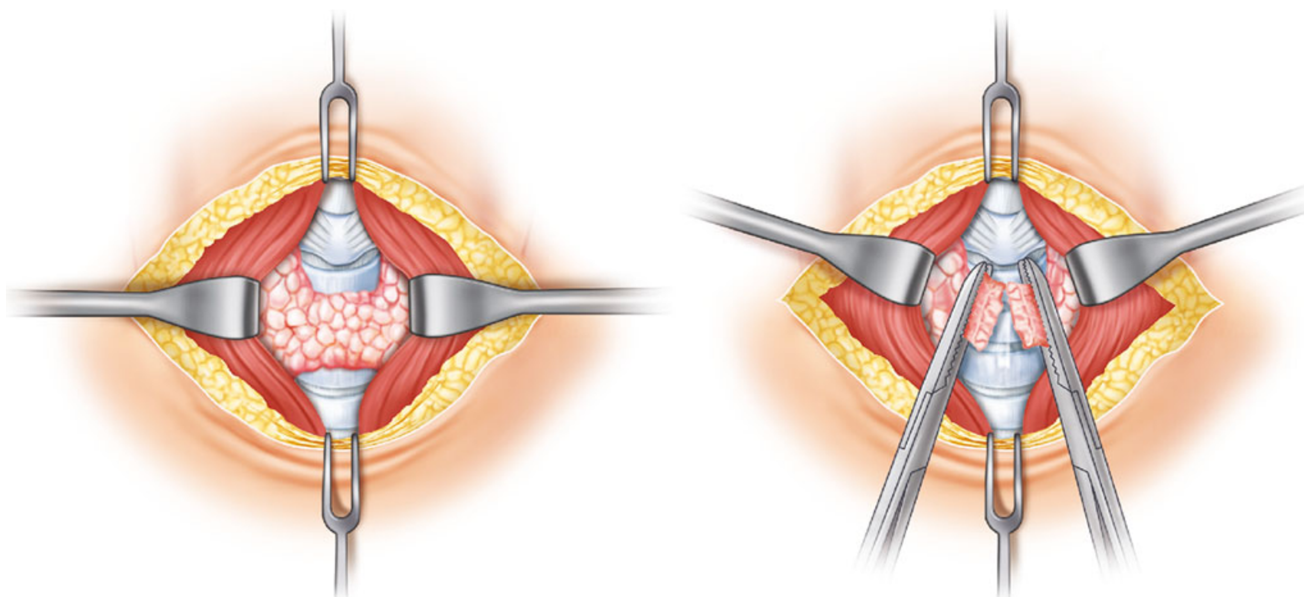

Fig. 2.32 The thyroid isthmus spans the trachea (*left*). It may require division (*right*)

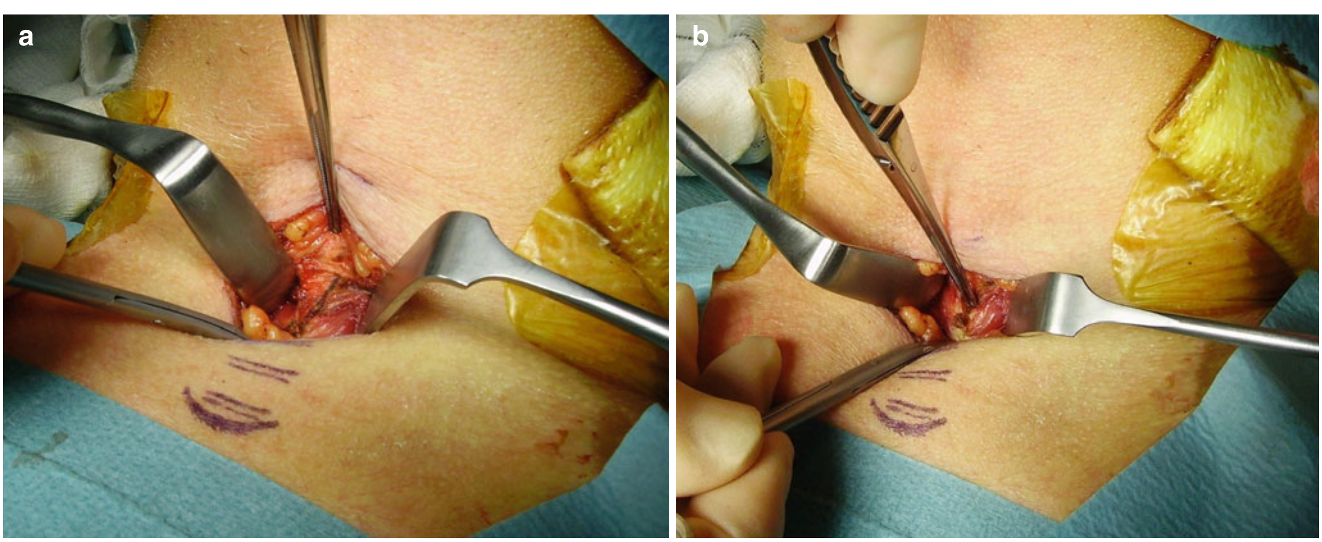

Fig. 2.33 The isthmus has been exposed (**a**). Using cutting diathermy it is gently divided (**b**). This needs to be done carefully as bleeding can be quite troublesome. The thickness of the isthmus can vary considerably. If cutting diathermy is used, be careful not to burn the underlying trachea. Diathermy can generate a lot of heat in the surrounding tissues if it is constantly applied

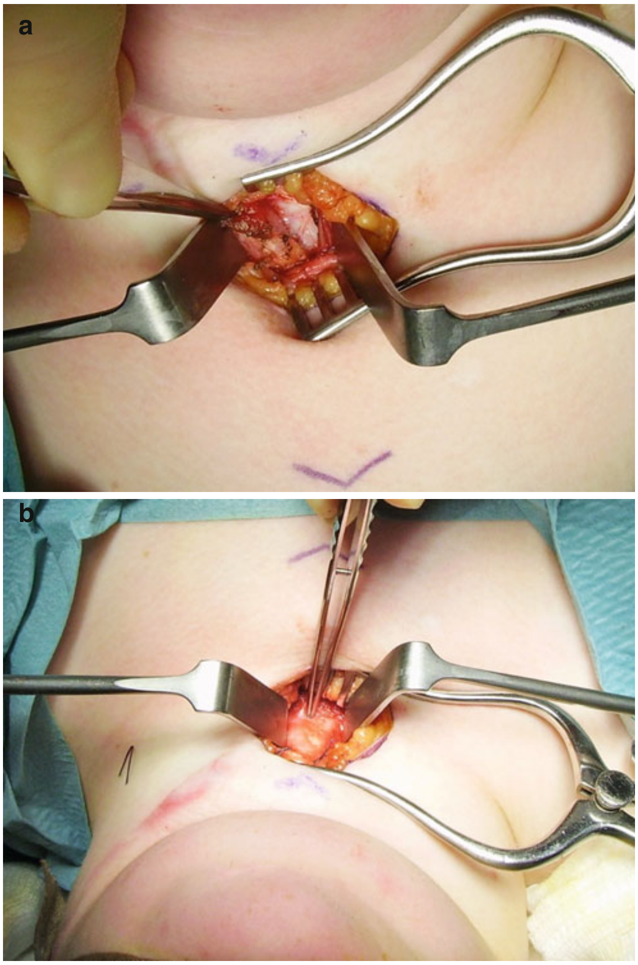

Fig. 2.34 Following division of the isthmus, some surgeons oversow the stumps. Cutting diathermy is no guarantee against further bleeding. The oversown stump on the patient's right is shown with the forceps (**a**). Both stumps are then gently retracted laterally (**b**)

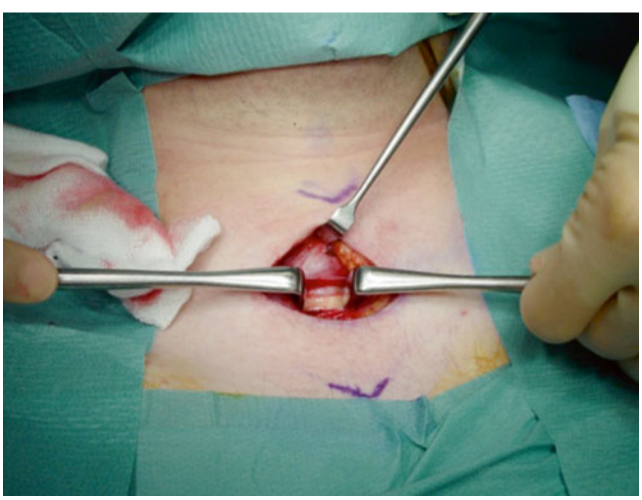

Fig. 2.35 In this case a clear view of the trachea is seen with the retracted isthmus uppermost. Patient's head is uppermost

Rupture of the endotracheal cuff is usually detected by the anaesthetist when ventilation pressures suddenly change. Depending on the clinical status of the patient and mode of

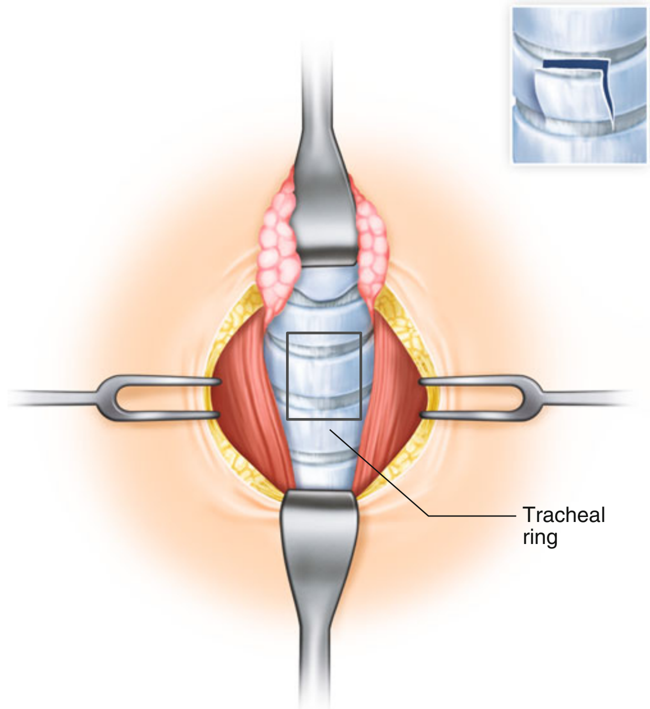

Fig. 2.36 The Björk flap is an upside down U-shaped incision. See text for details

ventilation this may or may not necessitate urgent placement of the tracheostomy tube. If the endotracheal cuff has not popped it is then slowly deflated by the anaesthetist and the endotracheal tube gradually withdrawn until its distal end is just above the hole in the trachea. The tracheostomy tube is then gently inserted. Its cuff is then inflated and it is connected to the ventilator (*see* Fig. 2.37).

Confirmation that the tube is in the correct place is by:

1. Direct visualisation
2. CO_2
3. Fibreoptically

Each center will have its own protocol.

At this stage it is important that an assistant continues to hold the tracheostomy tube in place to prevent it falling out. All retractors are removed and the wound is closed (skin only). The flange of the tracheostomy tube is then secured to the patient (*see* Fig. 2.38).

Skin closure should be watertight but not airtight. If the wound is made airtight, any leaked gases from around the tracheostomy tube (if the patient is on positive pressure ventilation) will pass out through the fenestration, but will not be able to escape and will track down the neck and into the mediastinum. This can result in tension pneumothorax or cardiac tamponade.

For the same reason, if the tracheotomy tube falls out and the patient has been re-intubated and ventilated, do not place an airtight dressing over the wound (*see* Fig. 2.39).

Finally, never forget the throat pack. Policies and procedures may vary between centers, but ultimately the surgeon should share some (if not all) of the responsibility to check

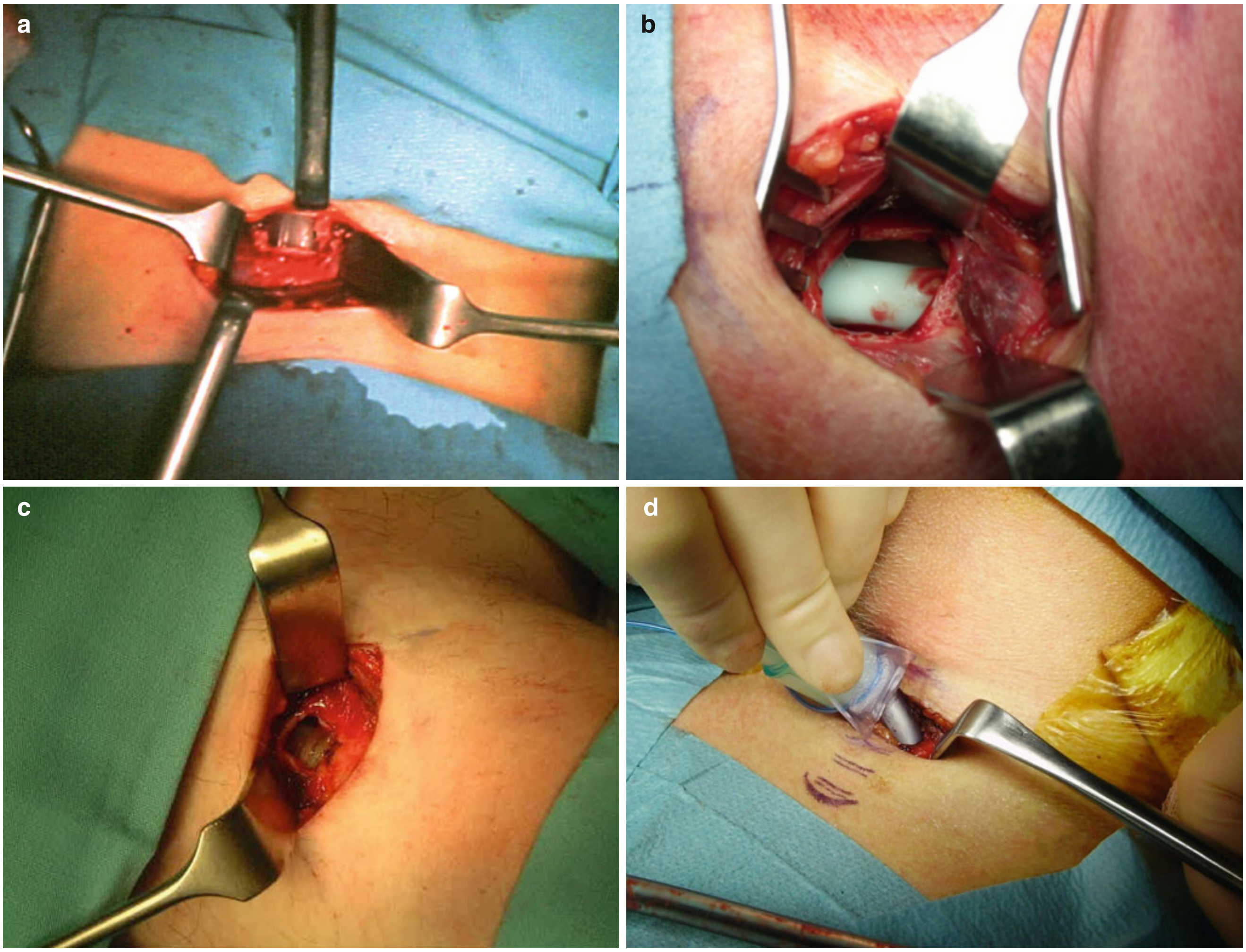

Fig. 2.37 A selection of cases following fenestration of the trachea and exposure of the ET tube or tracheal lumen (**a**–**c**). Following gradual withdrawal of the ET tube, the tracheostomy tube is placed (**d**)

Fig. 2.38 Secure the tube to the patient

Fig. 2.39 Massive surgical emphysema following dislodgment of a tracheostomy tube. The wound was covered over while the patient was being ventilated. A good example of applied anatomy and physiology

Fig. 2.40 Never forget the throat pack

at the end of the surgery. Surprisingly it is possible to extubate a patient with the pack in situ. Never assume that because the patient is extubated the pack must be out! (*See* Fig. 2.40.)

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3 Useful "First Aid" Measures and Basic Techniques

Michael Perry and Simon Holmes

Very often during their initial attendance, patients require some form of first aid while they are waiting to be investigated, treated, or discharged. Dirty wounds and burns, for example, should be irrigated and gently cleaned as soon as possible. A bag of saline, attached to an intravenous "giving set" and cannula is a simple way of providing a continuous flow of fluids if there have been burns to the eye.

3.1 Initial First Aid Measures

> Remember to check the patient's tetanus immunisation status in all wounds and determine the need for prophylaxis, based on local protocols.

3.1.1 Tacking Sutures

Gaping wounds should be gently cleaned and then loosely approximated either with adhesive tape (*e.g.*, Steri-Strips), or a few sutures. The choice of suture is not important at this stage as these will be replaced. Take reasonable-size bites, rather than try to cosmetically close the wound; the purpose of the suture is to stop any bleeding, realign the tissues to restore perfusion, and to protect the exposed underlying tissues. Ensure tags of tissue are not twisted or kinked on their pedicle—if left this way, they may become necrotic (*see* Figs. 3.1–3.5). Anecdotally, if a flap looks dusky, an adhesive glyceryl trinitrate (GTN) patch cut to shape may improve perfusion (make sure there are no medical contraindications).

3.1.2 Dressings

Saline or antiseptic-soaked dressings may be used to keep wounds from drying out and protect them from further contamination. If possible, take some photos—this helps reduce the number of times the wound needs to be inspected. If tissue has been lost (*e.g.*, animal bites), irrigate and clean the wound and loosely dress it. Choice of dressings is often a matter of personal preference.

With heavily contaminated wounds, meticulous debridement and copious irrigation are required before closure or dressing. Following this, it may be prudent to assume some pathogenic bacteria remain and an antiseptic-based dressing placed or systemic antibiotic commenced. Swabs taken at the time of initial cleaning may help choose an appropriate antibiotic if the wound becomes infected later. Many antiseptic dressings exist. Proflavin is a useful choice. It comes as a thick, oily liquid. Cotton wool is initially soaked in it and then thoroughly dried. This can then be applied to the surface of the wound. This technique is particularly useful when dressing an irregular contoured surface, such as the pinna. Small pieces of the dried cotton wool can be placed in the folds and contours, providing even contact and preventing haematoma formation. A head dressing is also required. With time, the dried proflavin often goes quite hard and may therefore need to be soaked with sterile water to enable the dressing to be gently removed (*see* Figs. 3.6 and 3.7).

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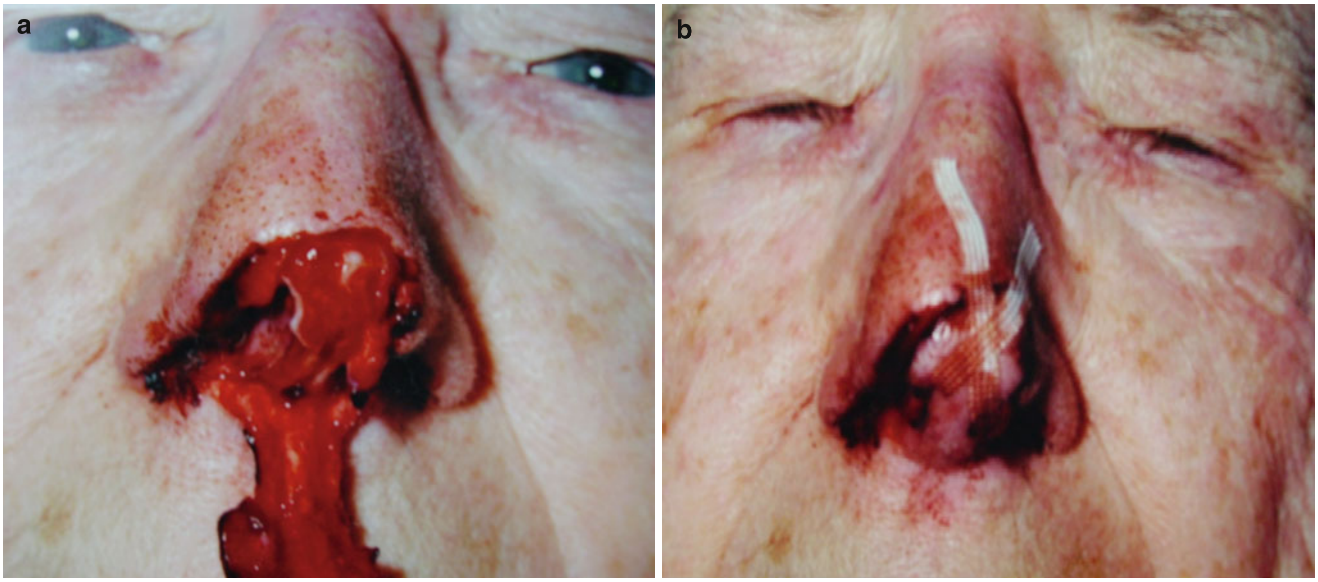


Fig. 3.1 Always realign twisted or kinked tissues to restore perfusion (**a**, **b**). If this had not been done in this case there would have been a good chance of losing of the flap (and a difficult reconstruction)

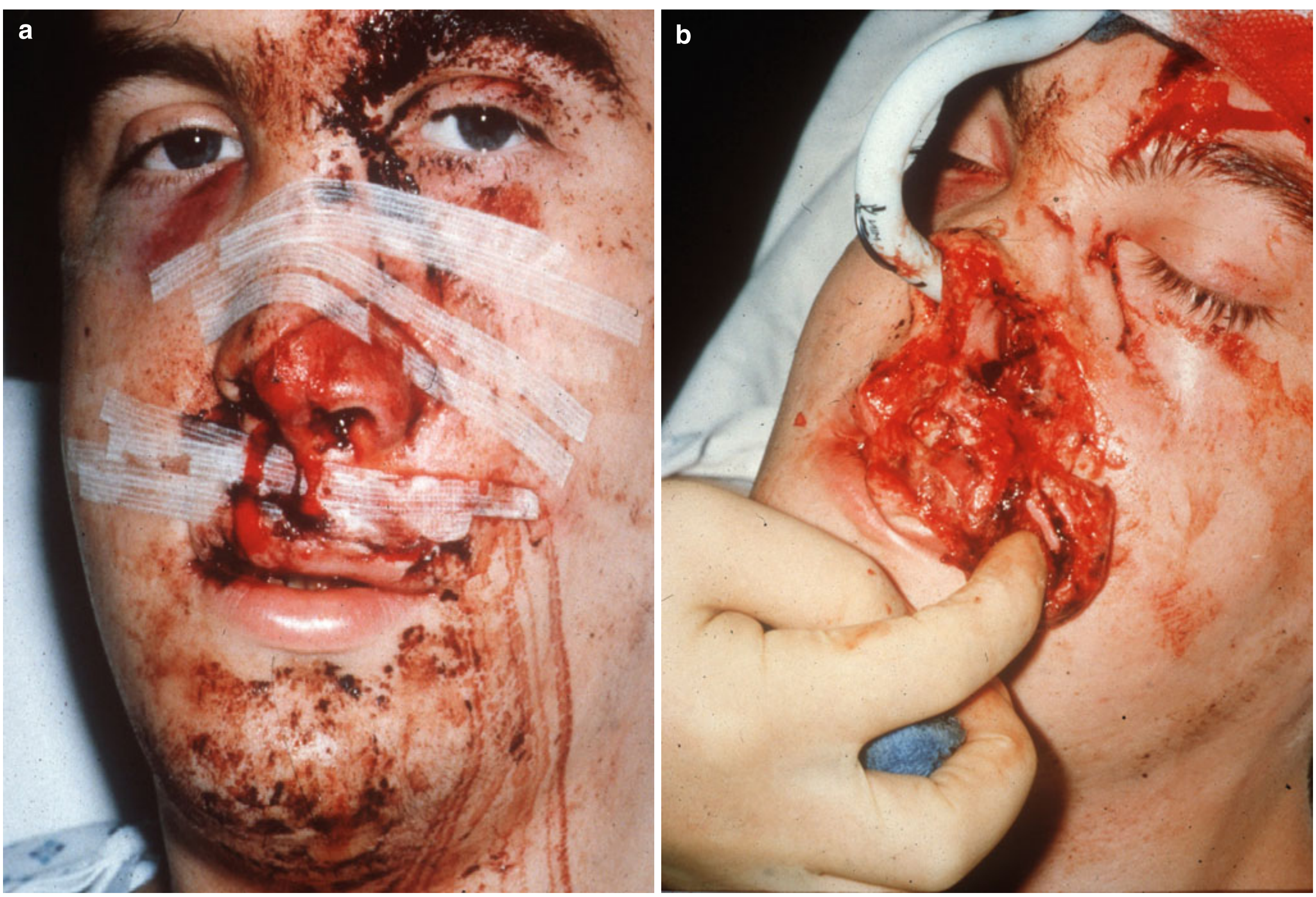


Fig. 3.2 A well-positioned flap (**a**). Examination under general anaesthesia was required to show the true extent of the injury (**b**)

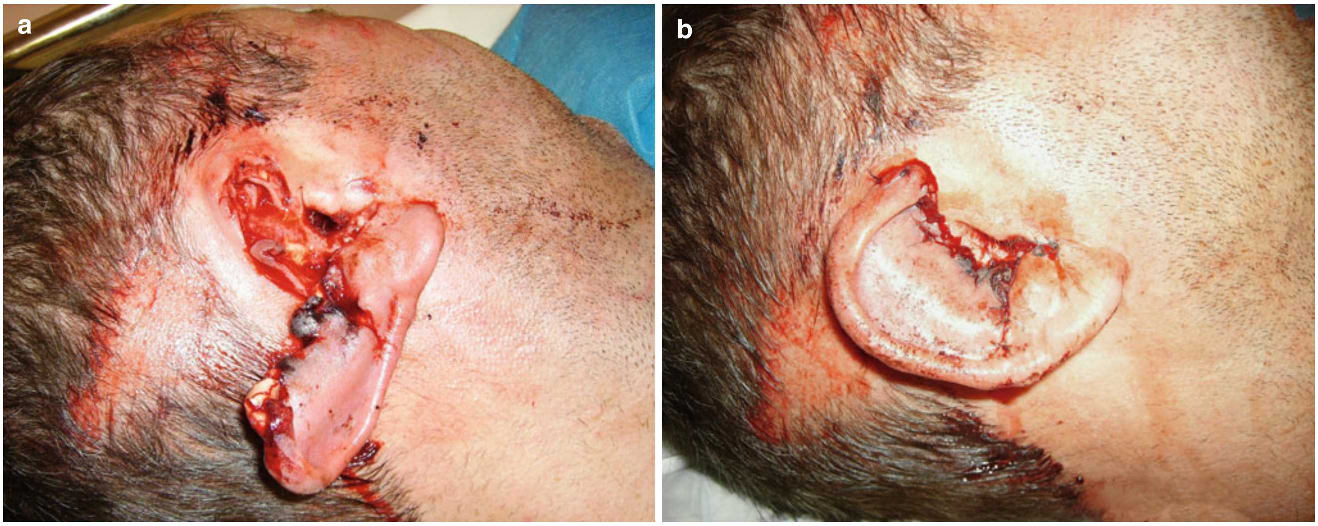


Fig. 3.3 Tacking sutures for partial avulsion injury. Before (**a**) and after (**b**) suturing

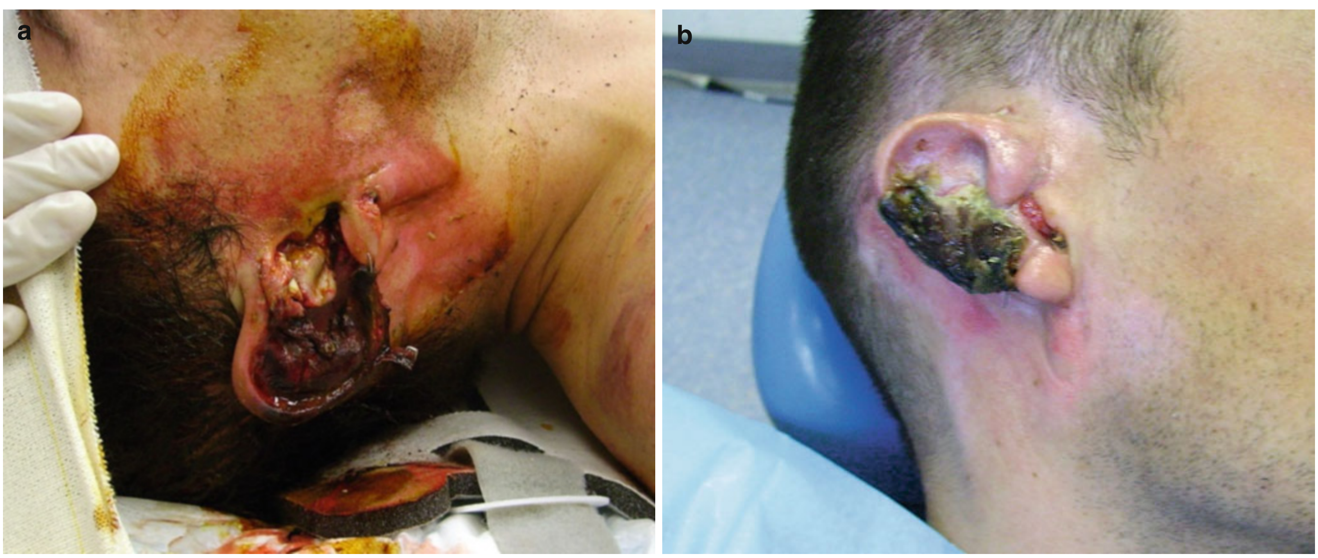


Fig. 3.4 This pinna was left to hang overnight, hidden under a head bandage. Consequently there was extensive necrosis and loss of tissue as shown in (**a**, **b**). A very difficult reconstruction is now required

Fig. 3.5 A good case for tacking sutures

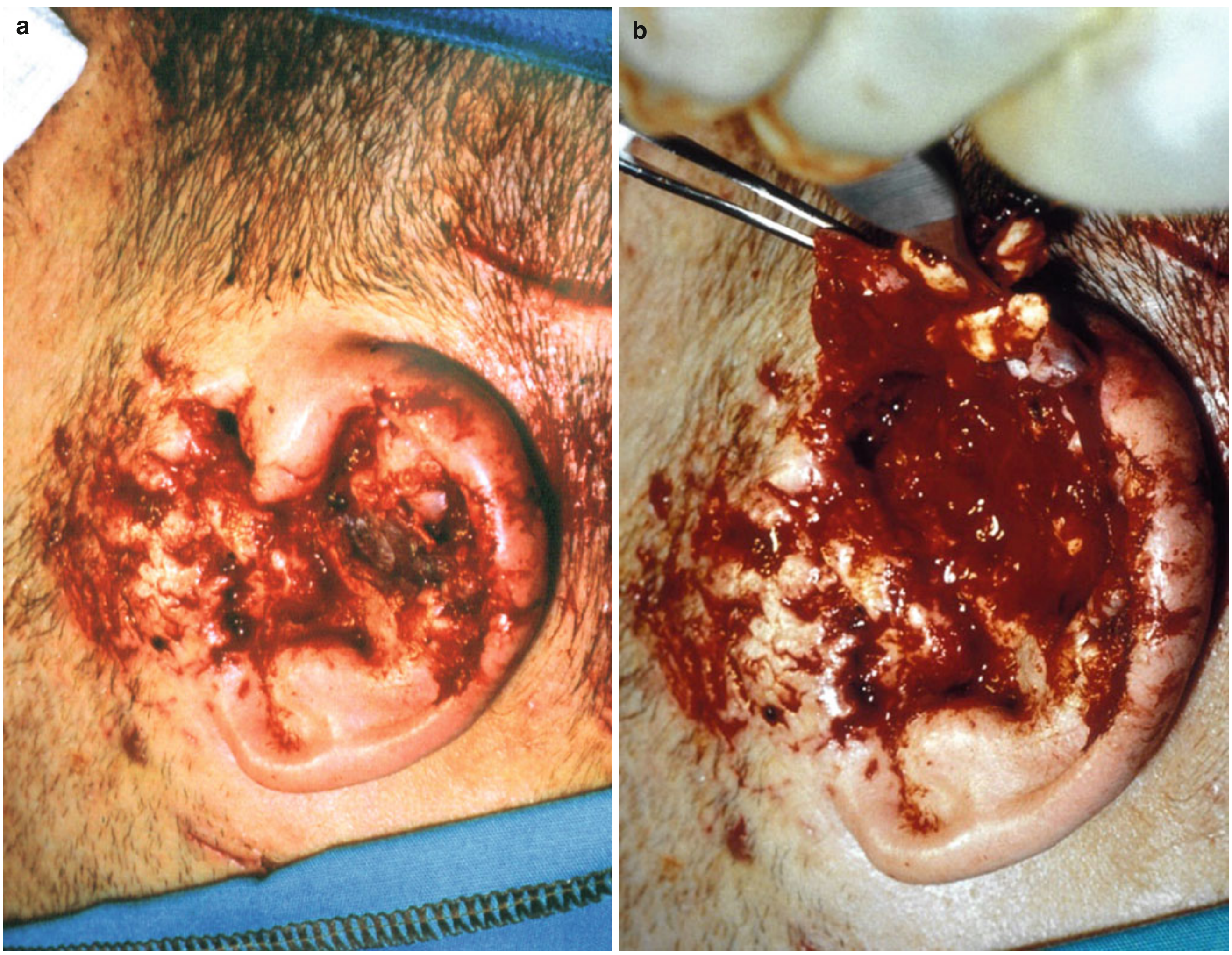


Fig. 3.6 Extensive damage to the ear. Following meticulous cleaning and debridement (**a**–**c**) a proflavin dressing was placed (**d**). Despite some small areas of exposed cartilage the wounds healed (**e**, **f**)

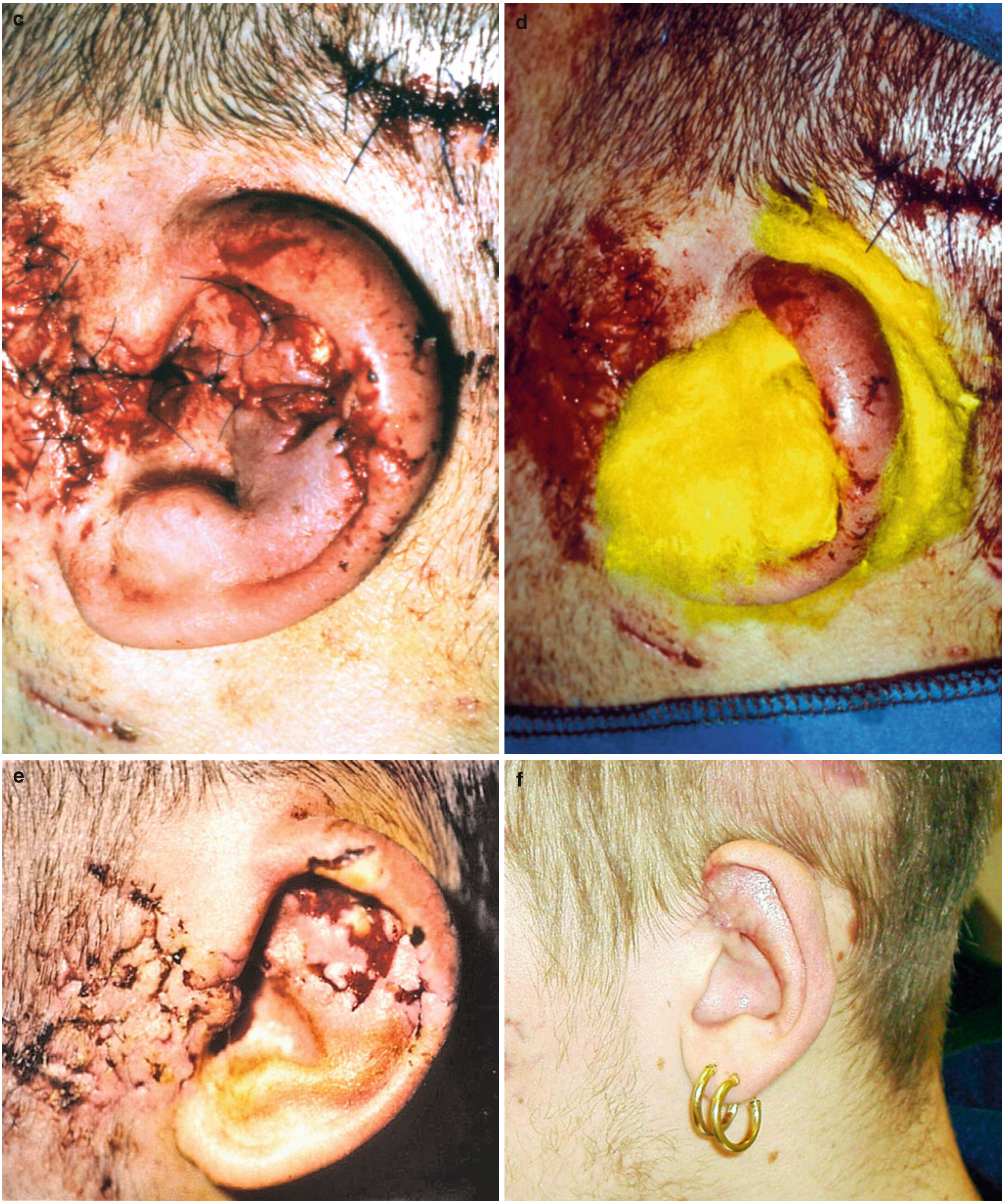


Fig. 3.6 (continued)

Fig. 3.7 A proflavin dressing following evacuation of a haematoma (delayed presentation with early signs of infection)

3.1.3 Bleeding from the Mouth

Most cases of bleeding from the mouth need only simple reassurance and getting the patient to bite firmly on clean gauze or a handkerchief over the wound (for at least 20 min). Local pressure is usually sufficient to arrest most capillary oozes. If bleeding persists, ask the patient to rinse their mouth out to clear any clots and look for the site of bleeding. This can then usually be dealt with by suturing or packing the wound with a haemostatic pack such as Surgicel. Arterial bleeding arising from the soft tissues is dealt with either by cautery or ligation of larger vessels. Local anaesthesia containing adrenaline may help. Bleeding from the exposed surface of a bone may require the application of sterile bone wax, but if the bleeding is from the ends of a fracture this will require reduction and temporary support. Do not put bone wax between fracture ends; some may be left behind following definitive repair and act as a foreign body. Useful pharmacological measures include antifibrinolytic agents such as tranexamic acid. If you are not familiar with these it is worth reading the information leaflet that comes in the packaging.

3.1.4 Bleeding from the Nose (Epistaxis)

Minor nose bleeds are a common problem following facial trauma. With minor injuries most bleeding arises from either Kiesselbach's plexus or mucosal lacerations, usually from the anterior part of the nose. Posterior epistaxes usually follow significant trauma to the midface or nasoethmoid region and can result in significant blood loss. Management of this is described elsewhere in this book. Remember to enquire about the patient's medical history and current medications (notably aspirin and warfarin) (*see* Fig. 3.8).

As a first aid measure, apply pressure to the cartilaginous part of the nose for about 20 min. If this does not control the bleeding, the site of blood loss needs to be identified and treated (*see* Table 3.1). This may be difficult in some patients and may require the use a headlight and suction. If the bleeding point is identified it can be usually be cauterized, either chemically (silver nitrate) or electrically (bipolar cautery). However, it is important not to extensively cauterize the septum. Overzealous bilateral cauterization increases the risk of septal perforation. If silver nitrate is used, have some saline to hand; this neutralises the silver nitrate if the burned area extends.

If bleeding continues despite these measures, anterior nasal packing will be required. Relative contraindications to packing include respiratory difficulties, but if bleeding continues, this has to be stopped. In these rare cases, airway control and assisted ventilation may be necessary.

A number of commercially produced nasal tampons exist and the choice is largely a matter of personal preference.

These include:

- Surgicel (oxidized cellulose)
- Merocel. This is a compressed foam polymer that is inserted into the nose dry. It expands when water is added, applying pressure over the bleeding points.
- Gelfoam (absorbable gelatin)
- Rapid Rhino anterior balloon tampon. This is inflated by air to apply pressure while its surface stimulates clotting.

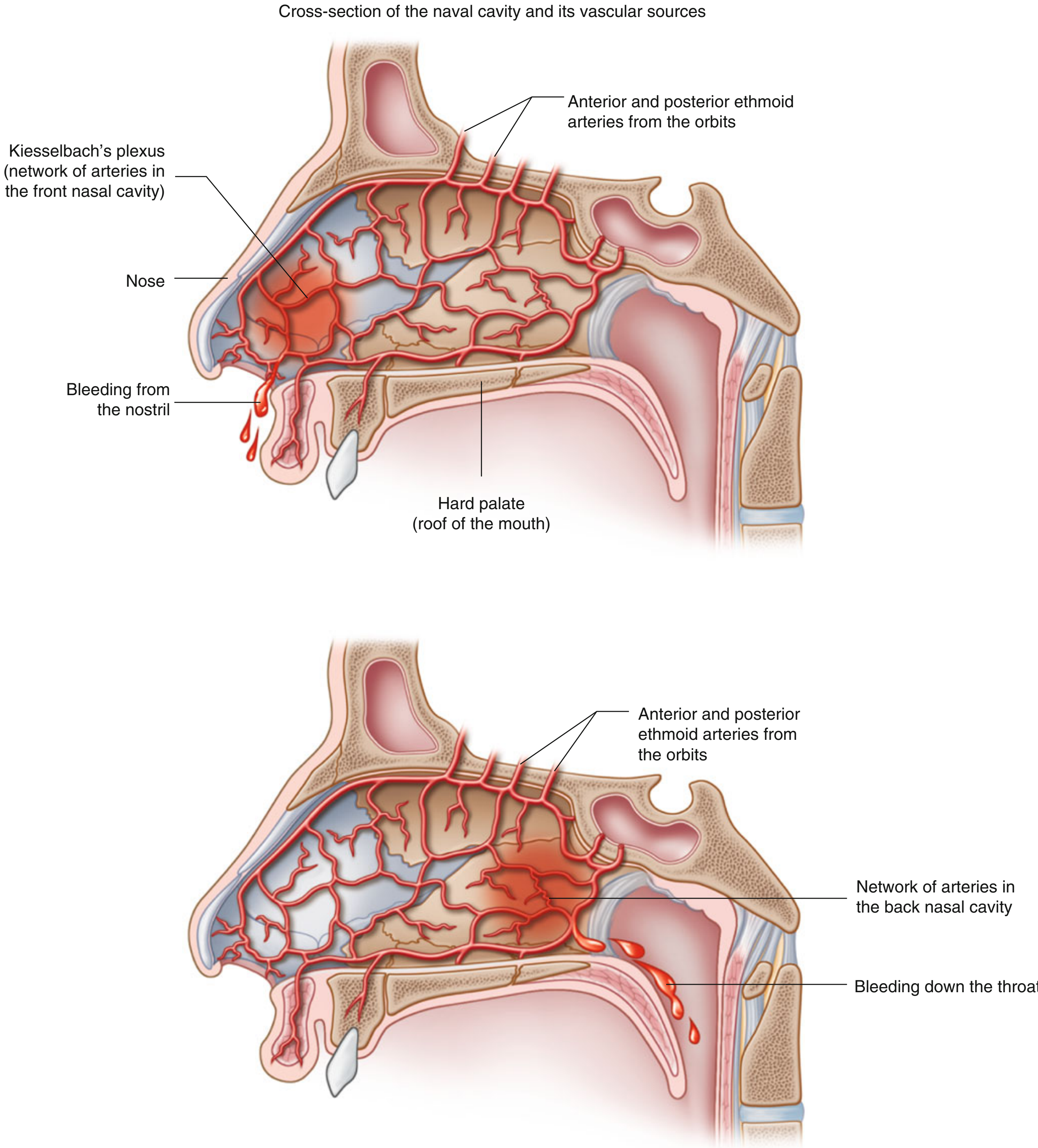


Fig. 3.8 Anterior and posterior epistaxes. These usually have differing aetiologies and require different treatments

Table 3.1 Management of anterior epistaxis

Topical anesthesia and vasoconstriction
Soak some cotton balls in a mix of 2 % lignocaine and 1:1,000 adrenaline. Put 1–2 balls into the bleeding nostril and leave for 10 min.
Evacuate any clots
Remove the cotton balls and gently clear the nose with suction (or have patient blow gently).
Identify bleeding source
Ongoing bleeding will appear as steadily dripping, bright red blood.
Cauterise the bleeding source
This can be done with either silver nitrate sticks or bipolar diathermy.
Packing
Anterior packing can be done with prefabricated nasal tampons. Apply a surgical lubricant to the tampon and gently insert it horizontally, along the floor of the nose.
Packing with gauze
If prefabricated devices are not available, ribbon gauze packing will suffice. This is usually impregnated with petroleum jelly or bismuth iodoform paraffin paste (BIPP). Remove the excess gel or paste before packing as this can be aspirated. Using long forceps and a nasal speculum, the material is lightly packed in a layered, accordion-type fashion. Pack as far posteriorly as the patient will allow.
Prescribe antibiotics

3.1.5 Pain Control

There are many ways to provide effective pain relief in trauma. These can be tailored depending on the cause. Resist the temptation to automatically give opiates to patients complaining of severe pain—it may not be the best analgesic, you may lose your ability to assess any head injury, and the patient may vomit (which may commit them to admission or a computed tomography [CT] scan). Nerve blocks placed at key sites where large nerve trunks are accessible (*e.g.*, Inferior alveolar nerve, infraorbital nerve, supraorbital nerve) enable large areas to be anaesthetised without overdosage. Many simple procedures can then be carried out in this way (*e.g.*, replacing a tooth, suturing or cleaning the face). With mandibular fractures, pain relief can be obtained by infiltrating local anaesthesia around the fracture site, a practice similar to the "haematoma block" used in orthopaedics. Alternatively, an inferior alveolar nerve block can be given. If the neck is "clear" a soft collar can be used to support the mandible.

> All patients should receive antibiotics (usually anti-staphylococcal). While packs are in situ, they are at risk of developing sinusitis or toxic shock syndrome.

3.1.6 Temporary Splinting of Teeth

Avulsed or subluxed teeth and dentoalveolar fractures should be reduced and splinted as soon as possible. Although definitive treatment may be required under general anaesthesia reduction should not be delayed until then. Splints can usually be applied under local anaesthesia. The tooth/teeth are gently repositioned and supported. Many different types of splint exist, but the simplest is a combination of wires and adhesives. Platting 3 or 4 wires together gives added strength and surface area to facilitate adhesion, while maintaining some flexibility. Any tears in the mucosa should be sutured at the same time.

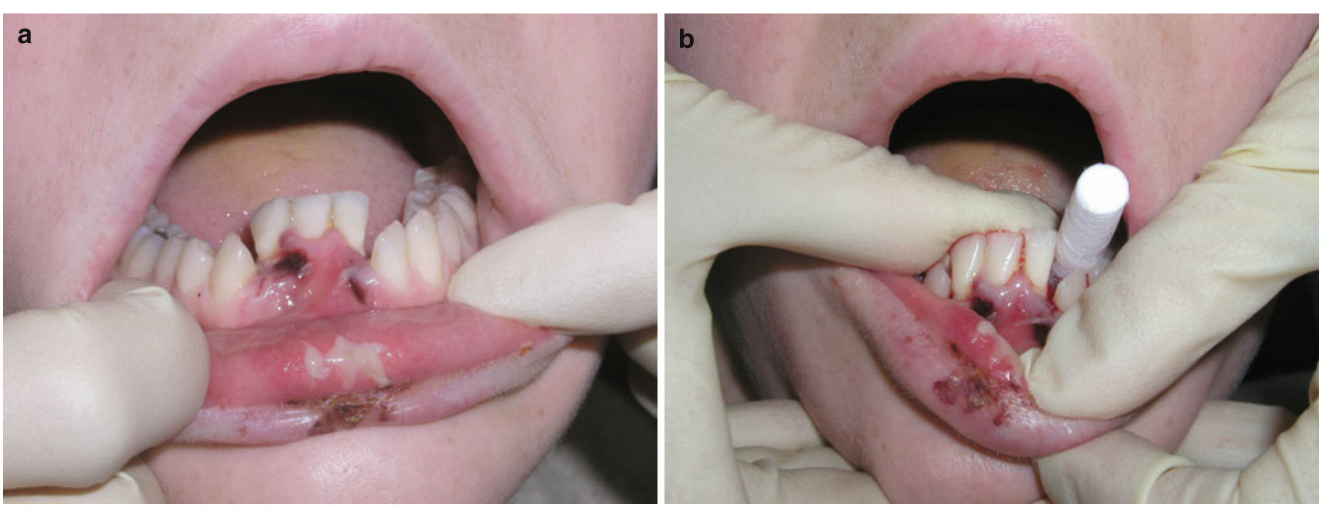


Fig. 3.9 Initial presentation of a dentoalveolar fracture (**a**). This fracture was reduced under local anaesthesia (**b**)

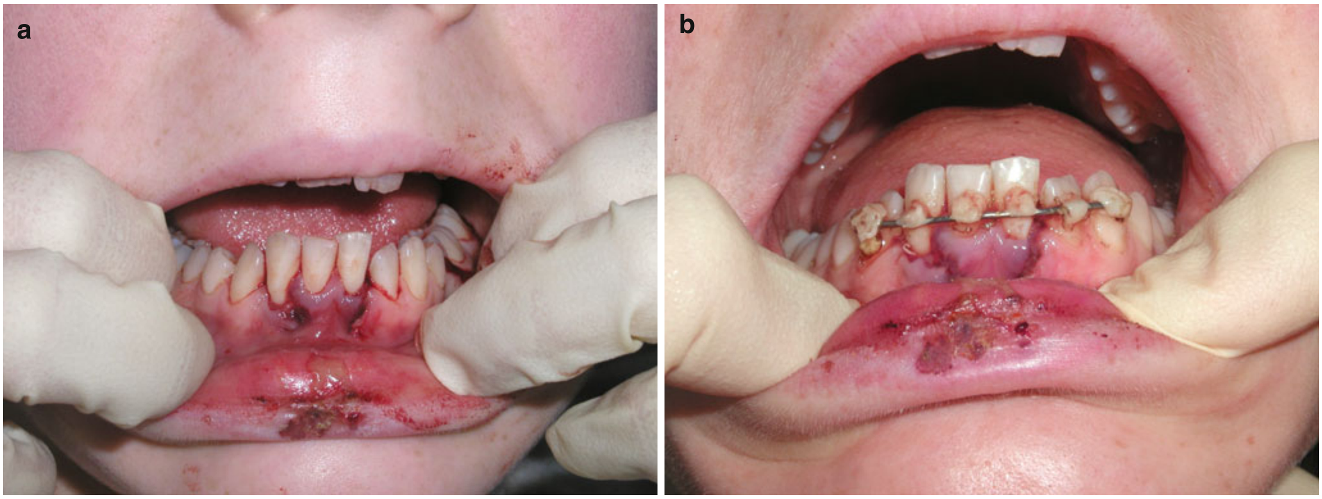


Fig. 3.10 A splint was applied using a wire (**a**) and dental adhesives (**b**)

Fig. 3.11 A similar arrangement for the upper teeth

3.2 Temporary Stabilisation of Mandibular Fractures

3.2.1 Bridle (Tie) Wire

If a mandibular fracture can be reduced manually, a "bridle" or "tie" wire should ideally be passed around the teeth on either side and tightened. This provides temporary support, preventing painful movement. In a sense, this can be regarded as the maxillofacial equivalent of an orthopaedic backslab. It is purely a first aid measure and should not be considered as definitive treatment (although anecdotally some minimally displaced fractures have been successfully managed this way) (*see* Figs. 3.12, 3.13, 3.14 and 3.15).

By itself, or in conjunction with intermaxillary fixation (IMF), this should be considered in all mobile mandibular fractures when significant delays in repair are anticipated. To allow a fracture to simply "hang" unsupported is not only painful for the patient, but will aggravate swelling, bleeding, and possibly increase the risks of infection. Limb fractures are not sent to a ward unsupported (a back slab is usually applied)—neither should a mobile mandibular fracture. Bridle wires can also be used to support mobile dentoalveolar fractures in the upper jaw. Again, this is a first-aid measure and not definitive treatment.

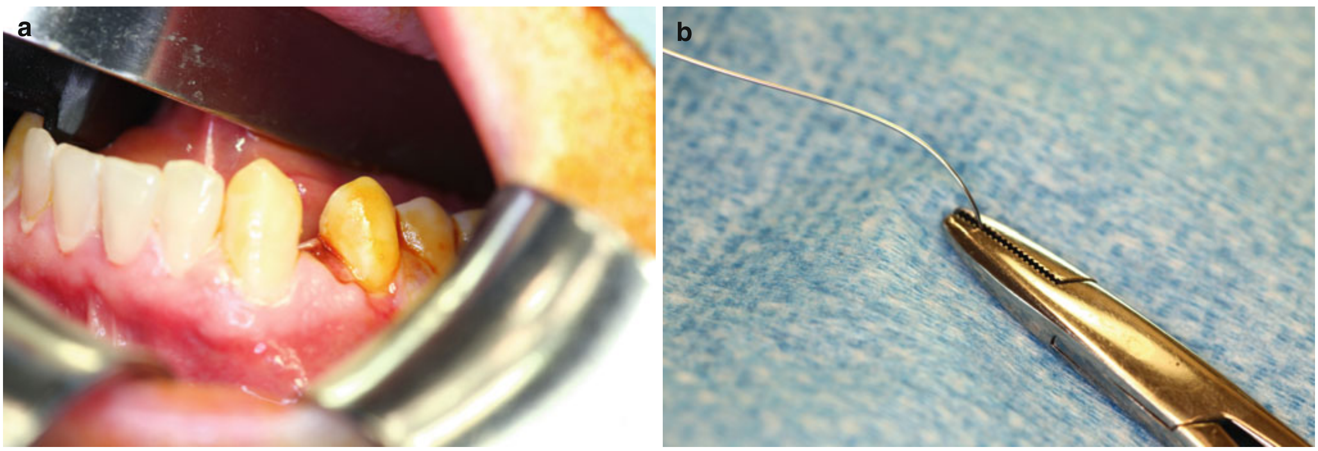


Fig. 3.12 A mandibular fracture extending between the canine and premolar (**a**). A thick wire is chosen (**b**)

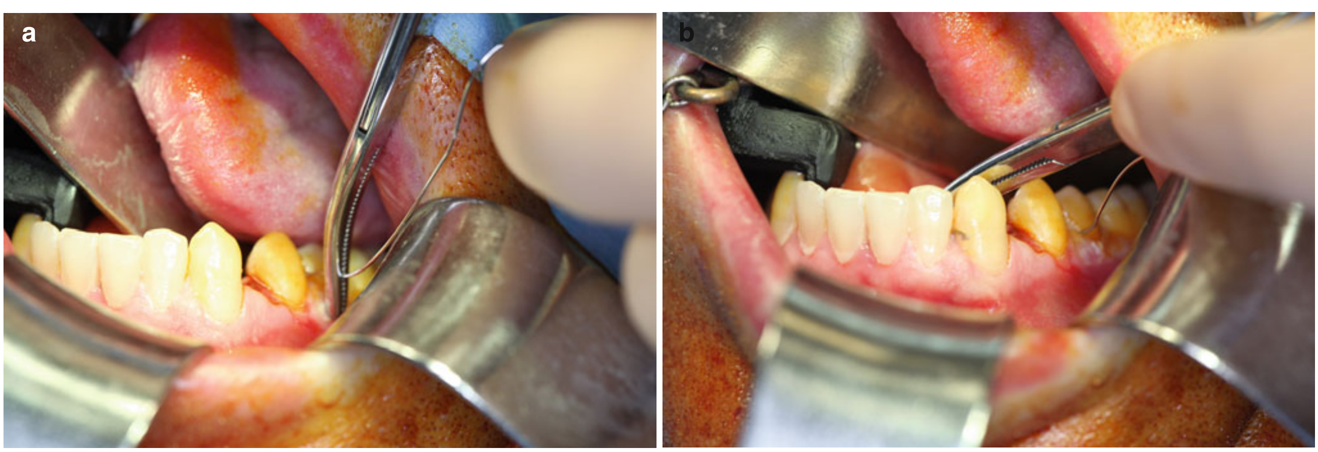


Fig. 3.13 The wire is passed around the teeth (**a**) on either side of the fracture (**b**)

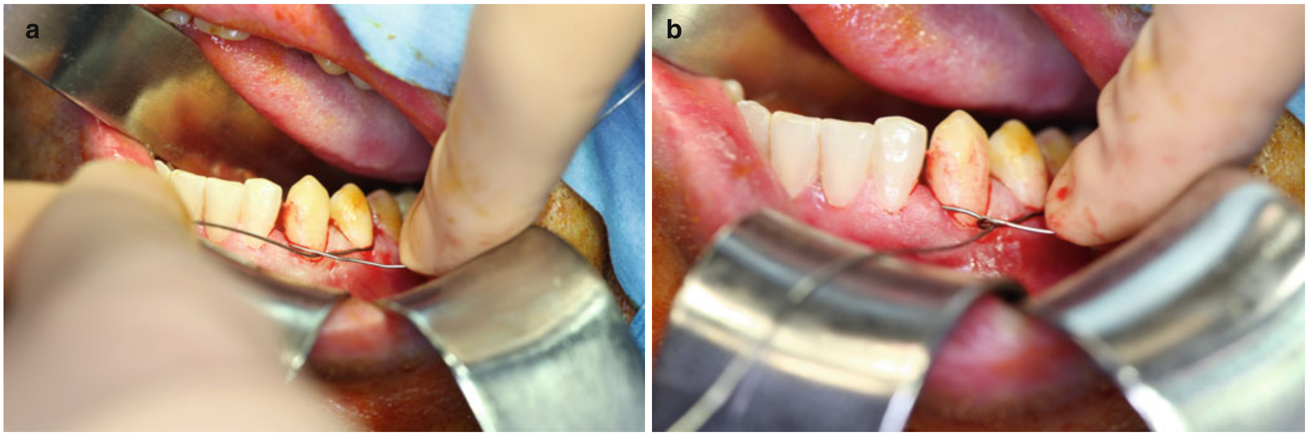


Fig. 3.14 The wire is then tightened while the fracture is manually reduced (**a**, **b**)

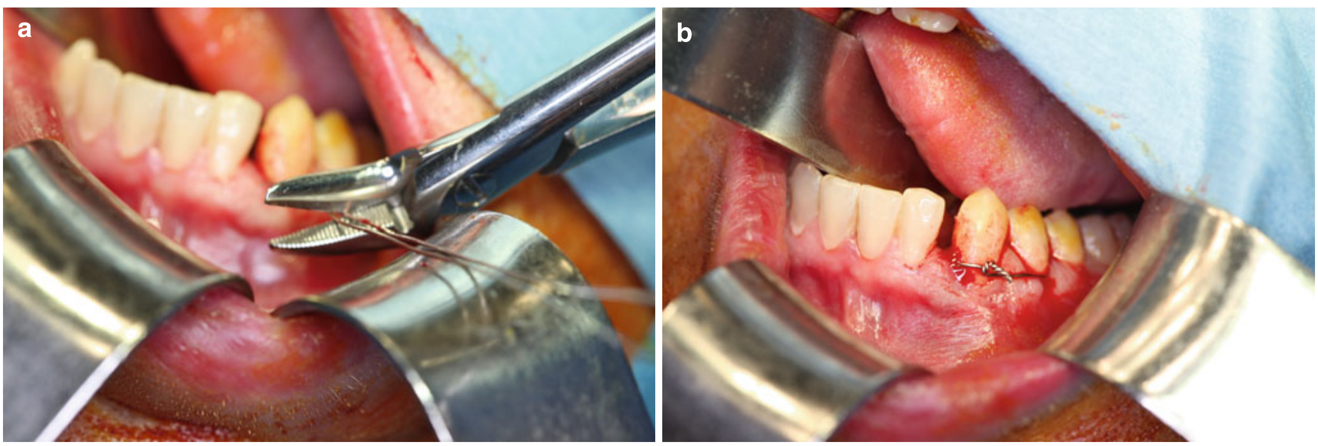


Fig. 3.15 The wire is then cut (**a, b**)

3.2.2 Intermaxillary Fixation (IMF)

Intermaxillary fixation (IMF), also known as maxillomandibular fixation (MMF) was first reported in the seventeenth century and is still commonly used in the management of mandibular fractures. It is based on the (erroneous) assumption that if the upper and lower teeth are repositioned back into the patient's preinjury occlusion, the bones will be anatomically reduced. This is not always the case, although *adequate* (but not anatomical) reduction is usually possible, *i.e.*, adequate enough to restore a functional occlusion. Although open reduction and internal fixation (ORIF) is now preferred in many centers, in those countries that do not have the resources for expensive plating systems, IMF is still commonly (and successfully) used.

Intermaxillary fixation is best suited for minimally displaced fractures, and in some fractures of the condyle (a

Table 3.2 Limitations in intermaxillary fixation

IMF is unsuitable for upper midface fractures (e.g., zygomatic, nasoethmoid).
When midface and mandibular fractures coexist, neither jaw can support the other. Internal (or external) fixation is still required.
Although the teeth may appear to be in occlusion (as viewed from the buccal/labial aspects), muscle attachments may still result in unrecognised displacement.
Pre-existing malocclusions may be difficult to reestablish.
If the dentition is depleted, there may not be enough teeth to provide stability.
IMF carries some risk to the patient. The airway may be compromised if they vomit. Intraoral/nasal bleeding may go undetected. Patients may lose weight. Care is required for alcoholic and epileptic patients. Respiratory function may deteriorate in patients with chest disorders (*e.g.*, asthma).
Patients dislike it.

controversial topic). Due to a number of limitations it cannot be used to treat all fractures (Table 3.2).

Despite these shortcomings, some studies have shown that patients treated with IMF may be less likely to develop postoperative malocclusions compared with internal fixation, although this is debatable. The main issue with IMF is it that it is unpleasant. It can also result in poor outcomes, notably with midface fractures. Some authorities believe that it has no role in trauma today.

3.2.3 Applying Intermaxillary Fixation

The principle of IMF is straightforward. "Arch bars," hooks, or eyelets (many types exist) are applied to the upper and lower dentition using circumdental wires or adhesives. These are then used to hold the teeth into occlusion. The more points of application that are used in each dental arch, the greater the number of elastics or wires that can be used to stabilise the bite. Thus IMF can vary from "light elastics" (commonly used in orthodontics) to "heavy elastics" or wires, providing almost rigid support to the occlusion (but not necessarily the fractures). This allows a "tailor-made" approach for each fracture. Not all fractures treated with IMF need to be rigidly supported, notably fractures of the condyle (*see* Fig. 3.16).

Many IMF products now exist, and the choice between them is often a matter of personal preference. Whatever fixation device is used, it is important to secure it carefully, so as not to damage the gingiva or periodontal pocket.

Another complication of inappropriately applied IMF is that the condyles can be distracted out of the glenoid fossae if the fixation is too tight (notably with wires). The fracture then heals in the incorrect position, only to be noticed once the IMF is released and the condyles return to their correct position. This is particularly important in condylar fractures. For this

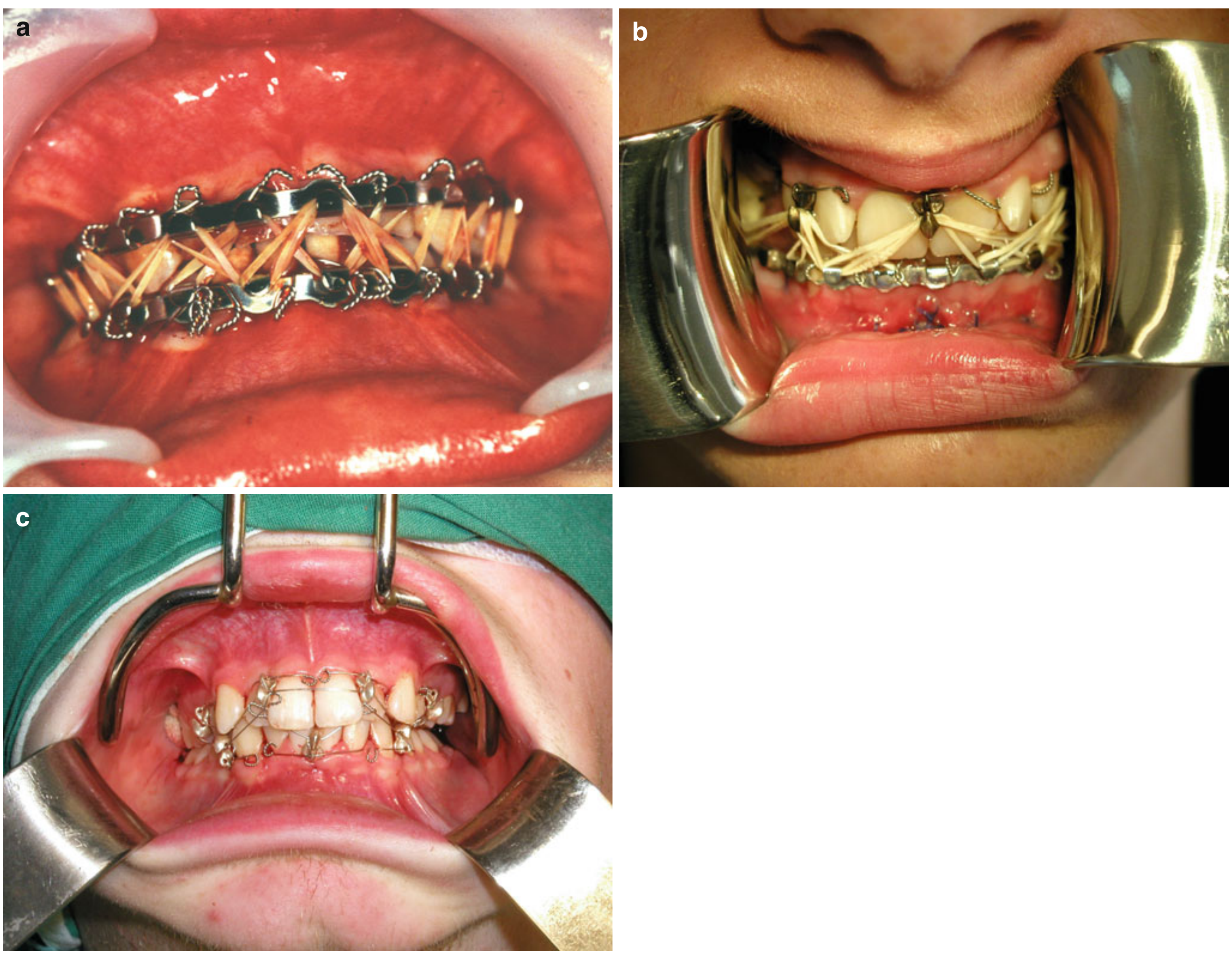


Fig. 3.16 (**a**–**c**) An assortment of IMFs

reason, elastics are often used rather than wires. These provide a degree of "give" and allow the condylar fragments to settle in their correct positions (remember that fracture immobilisation only has to be adequate and not necessarily rigid).

A small selection of techniques is shown. In the first two cases, a number of custom-made hooks and "Leonard" buttons have been fabricated. These are secured to the dental embrasure using fine wires. Both wires are passed through the dental embrasure. Each end is then passed around the adjacent teeth, one passing mesially, the other passing distally. The distal wire is then passed through a small hole in the hook, bringing it alongside the mesial wire. The two are then twisted and tightened together (*see* Figs. 3.17, 3.18, 3.19 and 3.20).

3.2.4 Intermaxillary Fixation "Hooks"

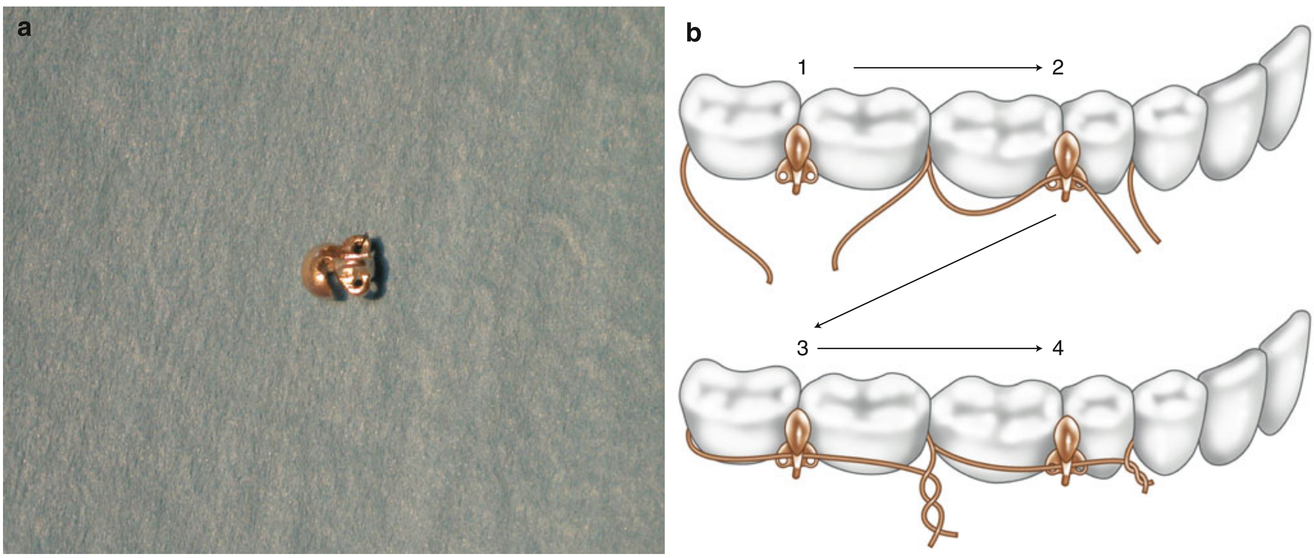


Fig. 3.17 An IMF "hook" (**a**) and circumdental wire arrangement (**b**)

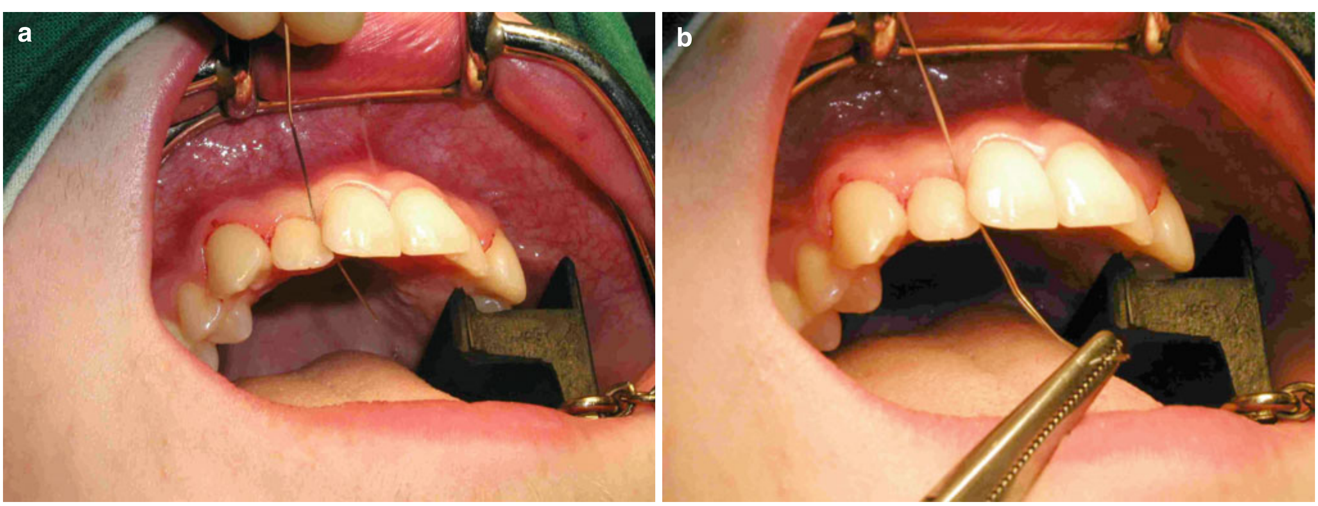


Fig. 3.18 (**a**–**k**) Application of an upper IMF hook using circumdental wire. *See* text for technique

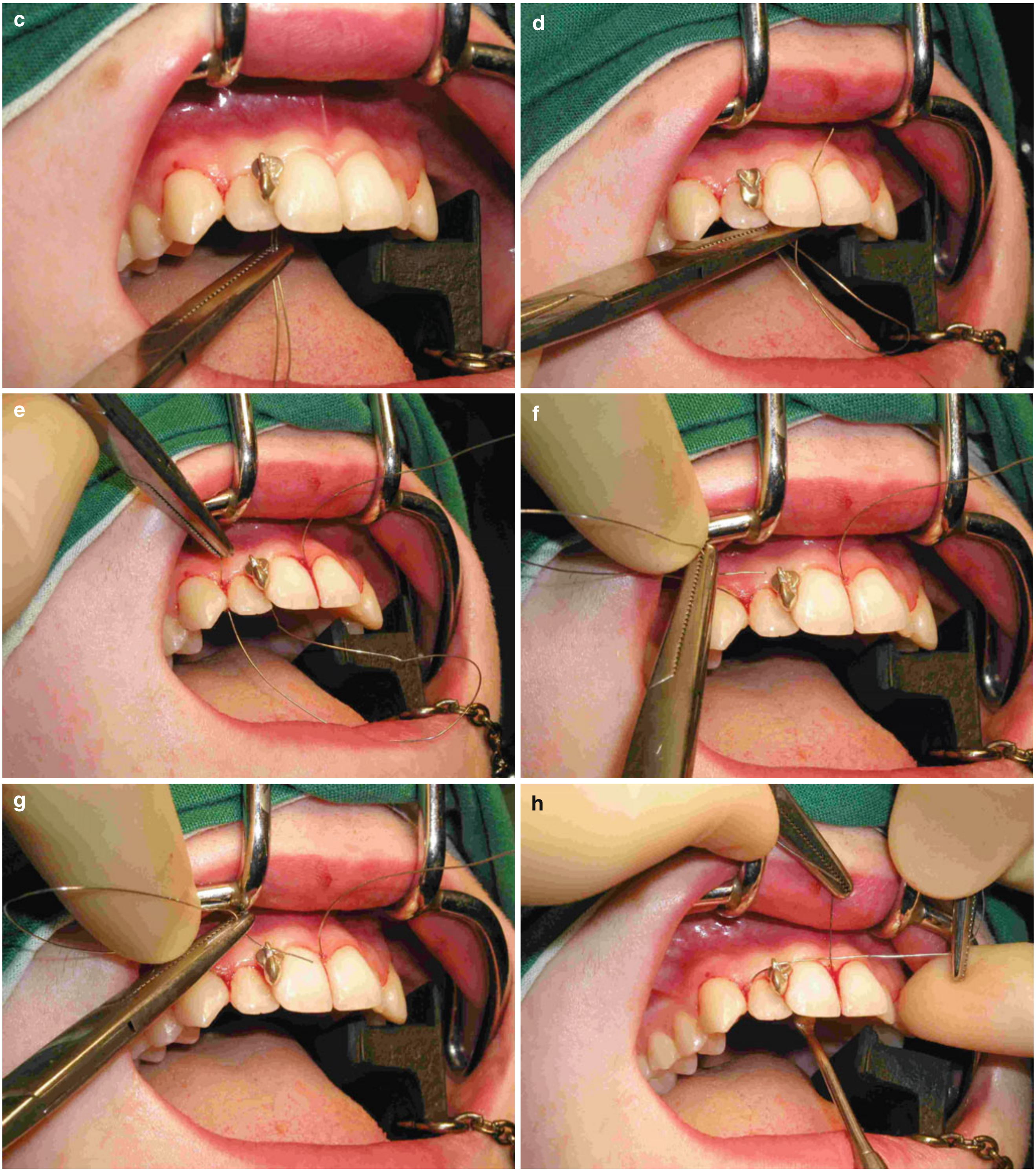
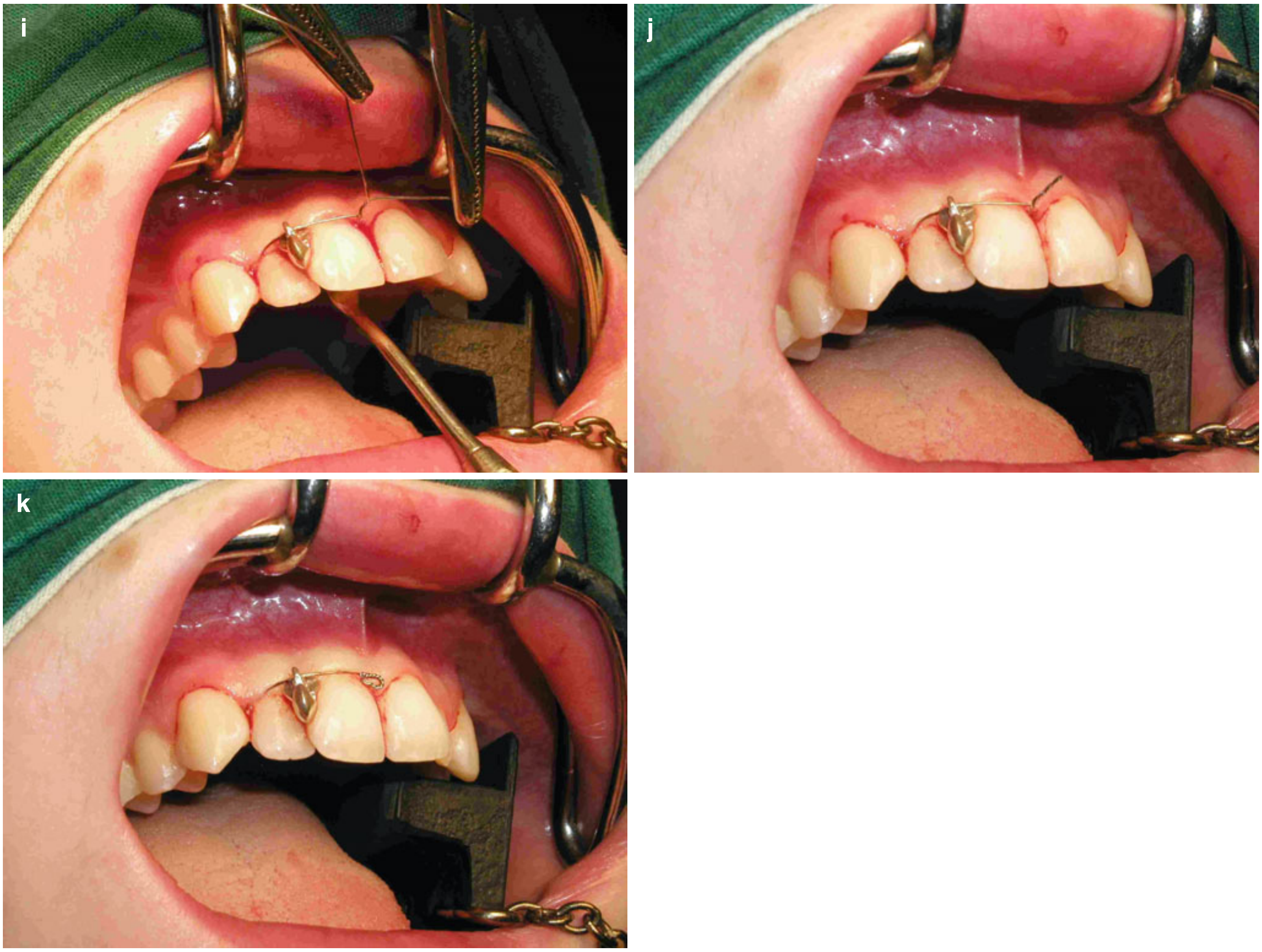


Fig. 3.18 (continued)



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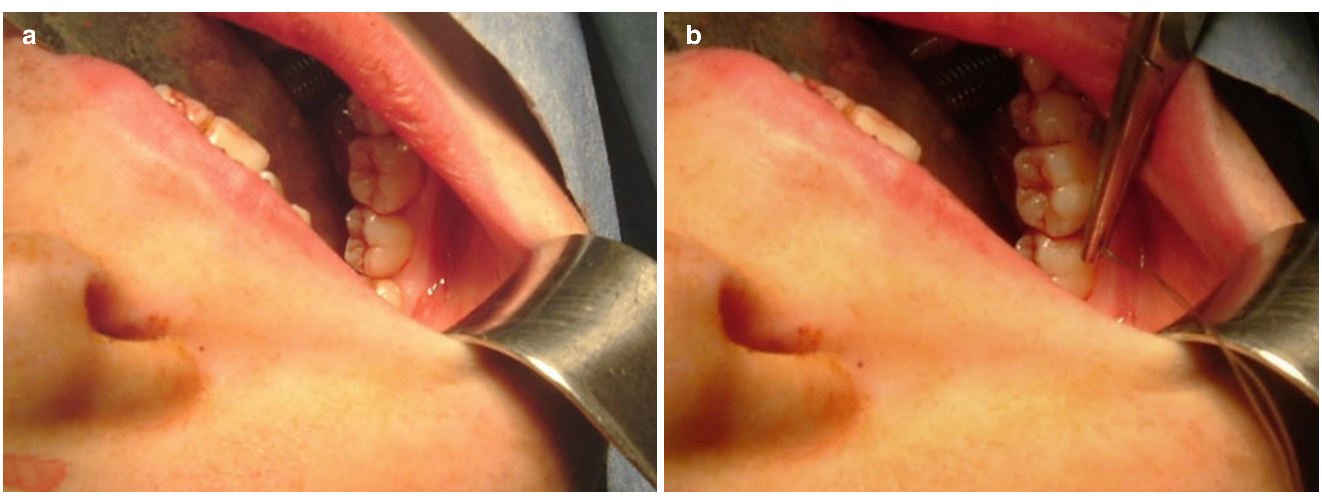

Fig. 3.19 (**a**–**h**) Application of a lower IMF hook using circumdental wire. *See* text for technique

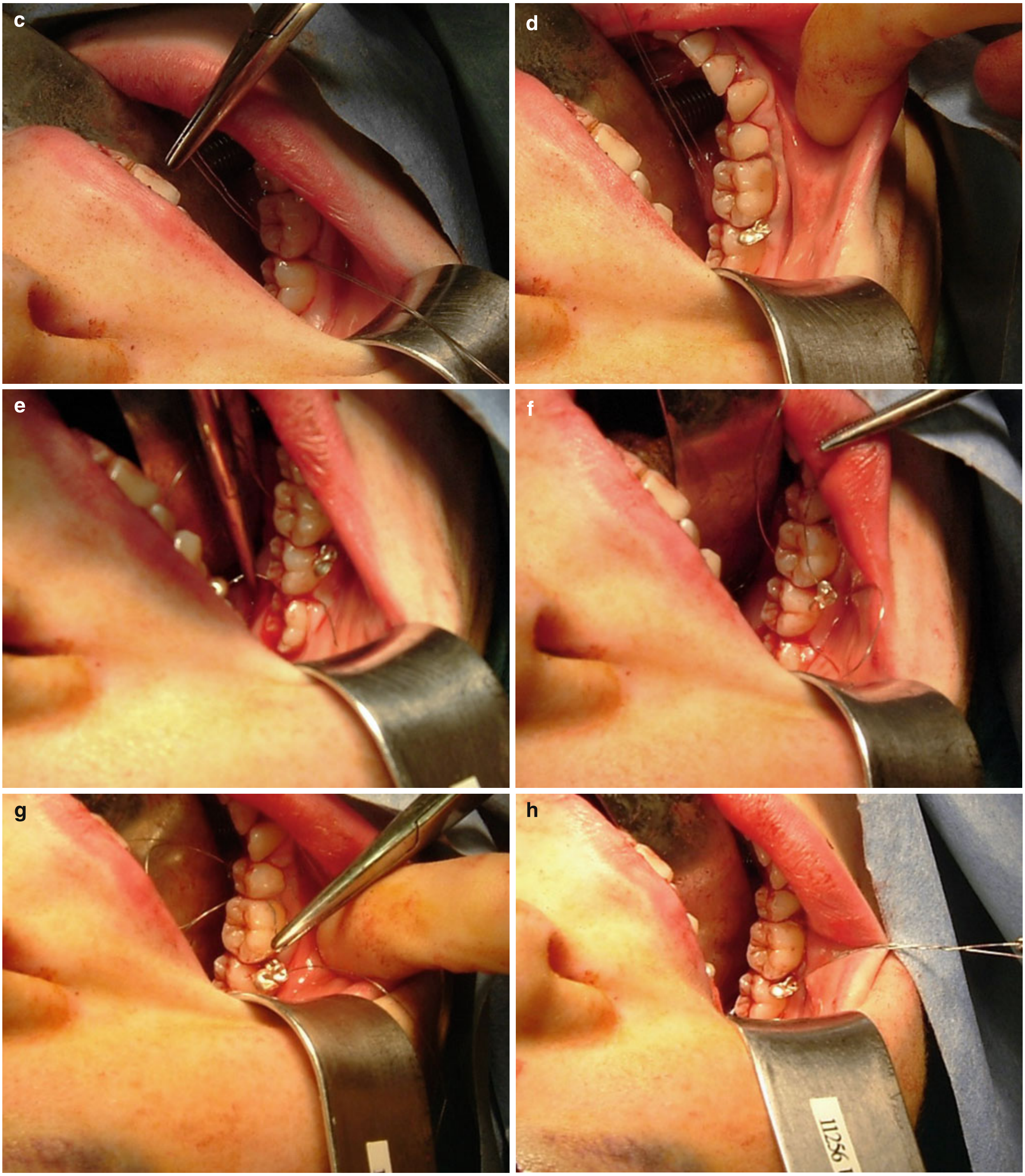

Fig. 3.19 (continued)

Fig. 3.20 Final "zig-zag" arrangement with elastics

3.2.5 Leonard Buttons

The use of IMF hooks and Leonard buttons requires at least one intact and firm tooth either side of the point of application. Positioning of these hooks and buttons is important. The ideal configuration is a zigzag design as shown, but depending on the dentition and the elastics (or wires) used they may be placed opposite each other. The number of hooks applied can also vary depending upon the degree of IMF that is required postoperatively. Typically, three or four hooks per jaw will enable a "moderate" degree of IMF (*see* Fig. 3.22).

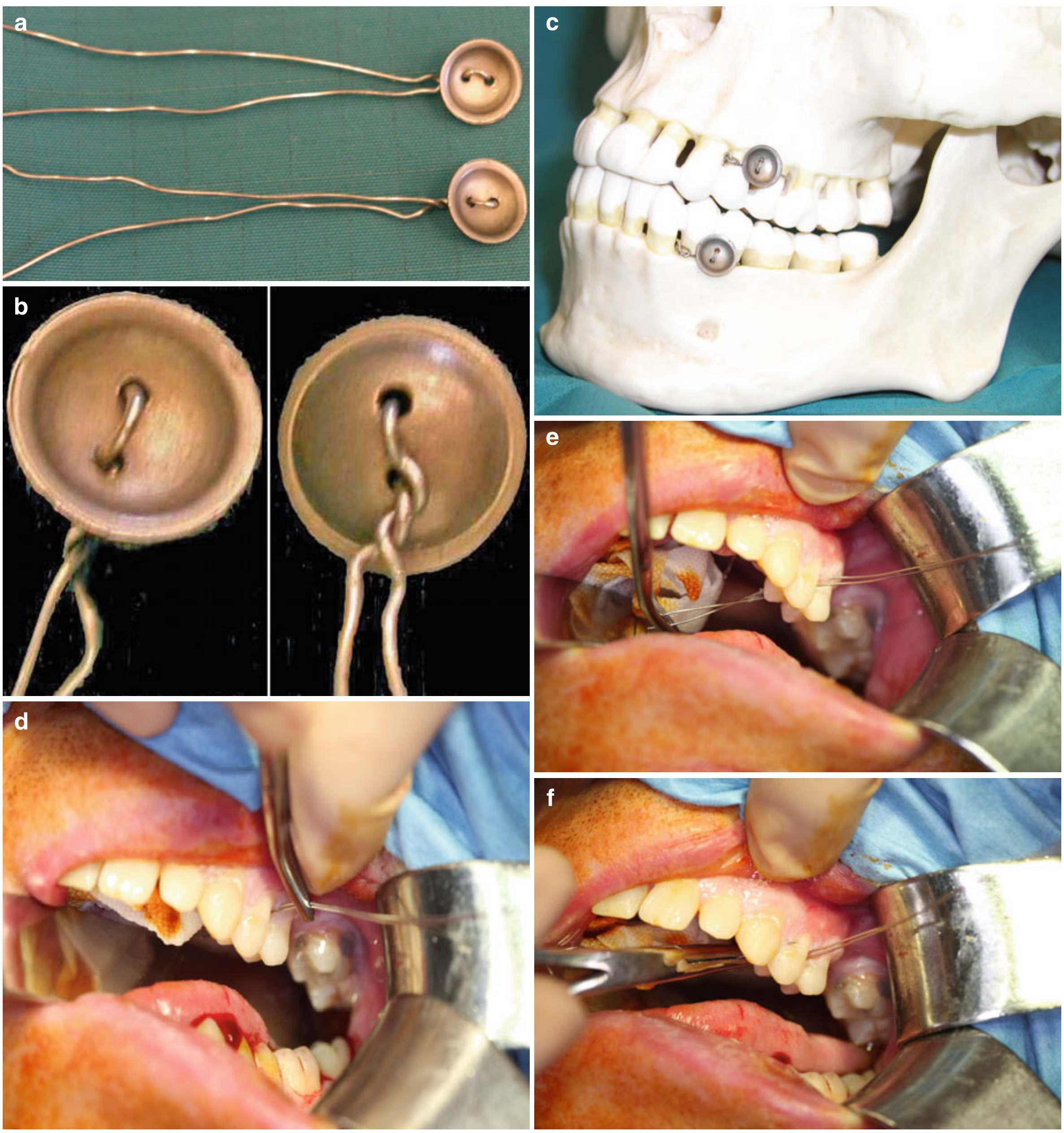

Fig. 3.21 (**a**–**c**) Leonard buttons and in situ positioning. (**d**–**l**) Application. This procedure follows the same principles and steps as for hooks

Fig. 3.21 (continued)

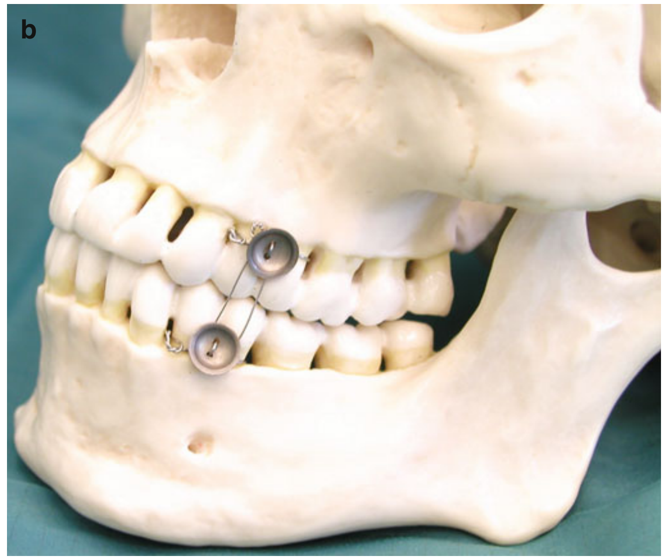

Fig. 3.22 (**a**, **b**) Leonard buttons in situ with elastic and wire

3.2.6 "Rapid" Intermaxillary Fixation

This is another method of applying IMF that follows similar principles to the IMF hooks and Leonard Buttons. Durable plastic circumdental ligatures with cleats are reported to speed up the process of applying IMF (*see* Fig. 3.23).

The plastic "hook" is seated in the embrasure between two teeth while the plastic ligature is passed around the neck of the distal tooth and then through the hook itself. This device has a self-locking mechanism similar to "cable ties" or wrist restraints used by the police. It also has the added advantage that there are no sharp points on the device, so the risk of needlestick injury is considerably reduced. This technique is certainly rapid, but probably not suited for prolonged periods of use or "heavy" IMF.

3.2.7 Intermaxillary Fixation Screws

Hooks, buttons, and ligatures rely on the presence of an intact dentition. They are therefore of limited usefulness in the partially dentate or edentulous patient, or when dentoalveolar injuries coexist. In such cases, bicortical bone screws ("IMF screws"), can be placed and used to support wire ligatures. These avoid the need for dental anchorage. Care is required in screw placement if there are any teeth nearby. An adequate number of opposing teeth is still required in order for the occlusion to be stable while held in IMF.

Intermaxillary fixation screws are a very rapid way of applying intermaxillary fixation. They come in variable lengths and are both self-drilling and self-tapping. Each screw is secured to the dentoalveolar bone by passing it between the roots of the teeth either side. Both buccal and lingual/palatal cortices of the bone must be engaged for the screw to remain secure. Because it is a blind procedure, radiographs of the jaws are required beforehand to make sure there are no unerupted teeth and to check root morphology of the adjacent teeth (*see* Figs. 3.24, 3.25, 3.26, 3.27 and 3.28). In the mandible, careful placement is required to avoid injury to the inferior alveolar nerve.

Fig. 3.23 (**a**–**e**) Application of “rapid” IMF. *See* text for details

3.2.8 Other Alternatives

Arch bars and circumferential tie wires are two further ways of securing IMF. Arch bars come in many forms: from standard "off the shelf" designs, to custom-made splints requiring some delay in fabrication and costly laboratory work. Nevertheless, the latter can provide an enhanced degree of rigidity and still play a useful role. These are secured by circumferential dental wires. Standalone, circumferential tie wires are rarely used nowadays due to the superior design and application of hooks and buttons. But they are probably still worth knowing about, in case these are not available (*see* Figs. 3.29, 3.30 and 3.31).

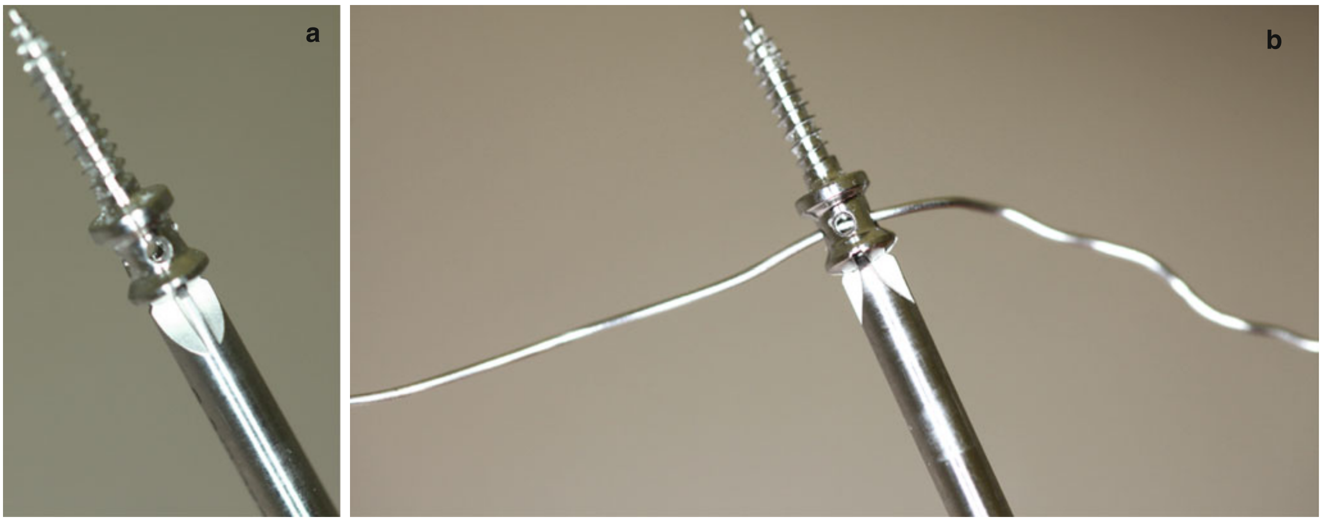

Fig. 3.24 IMF screw without wire (**a**) and with wire (**b**). These have two small perpendicular holes in the head to facilitate wire fixation

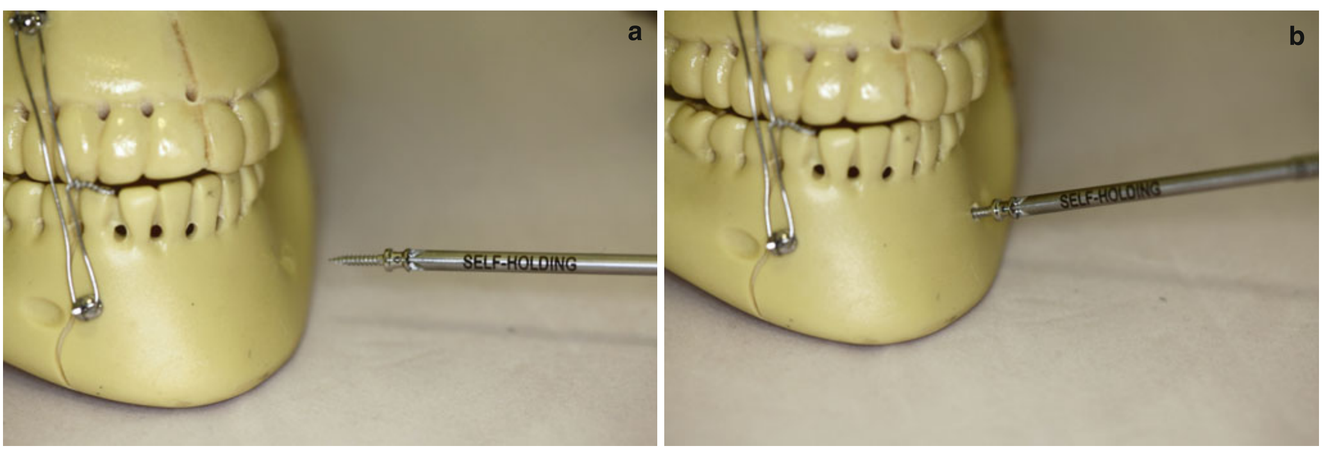

Fig. 3.25 (**a**, **b**) The screws are both self-drilling and self-tapping. No drill is required

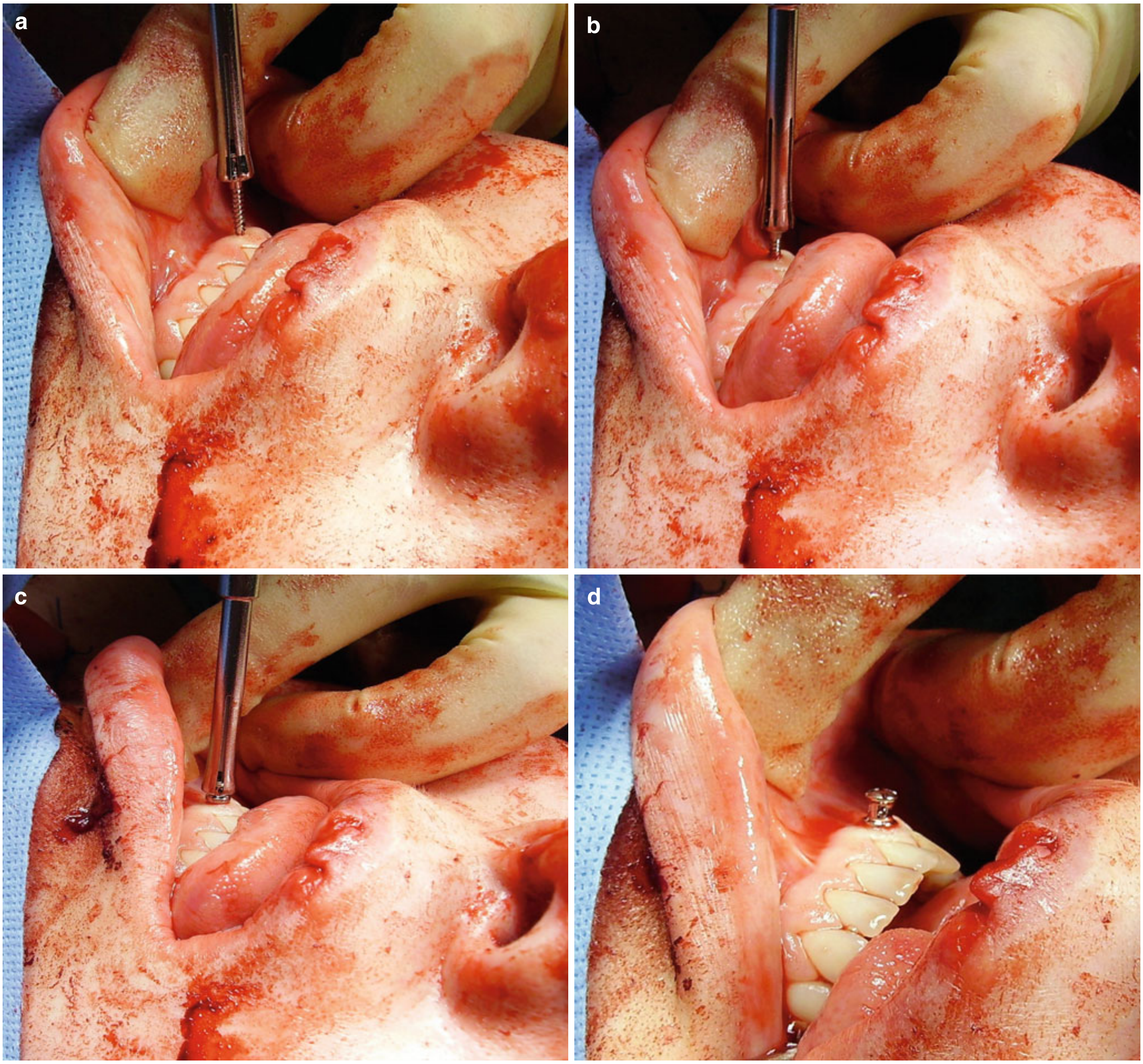

Fig. 3.26 (**a**–**d**) Application of mandibular IMF screws

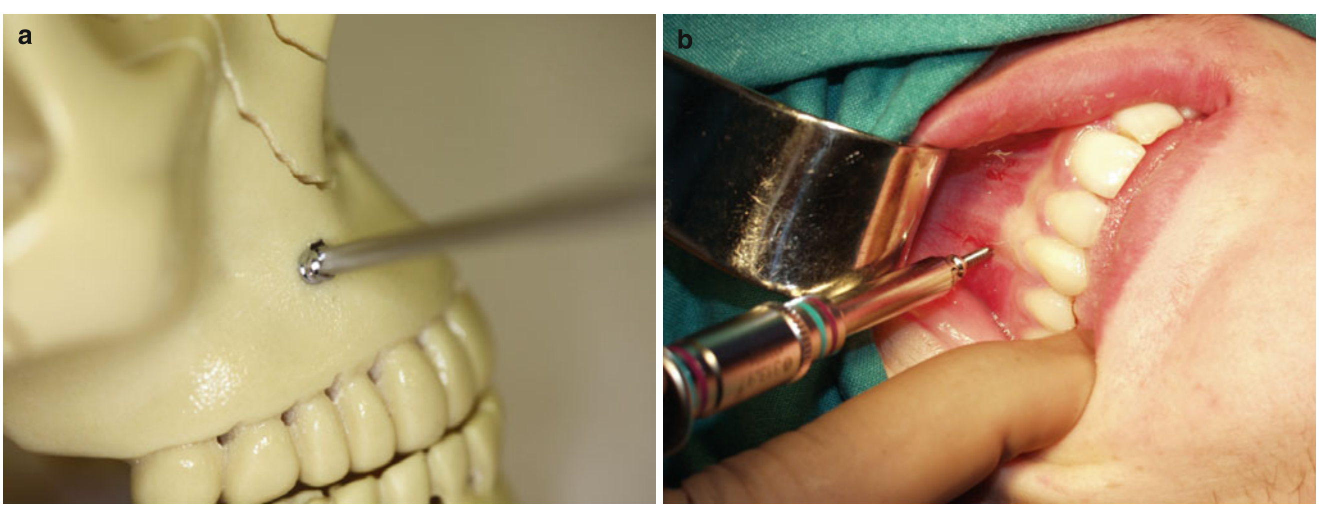

Fig. 3.27 (**a**, **b**) Application of IMF screws to the maxilla

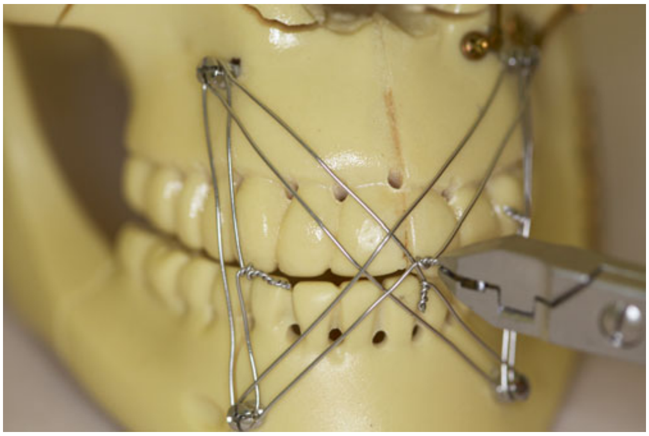

Fig. 3.28 Very rigid IMF is possible using wires

Fig. 3.29 Custom-made splints

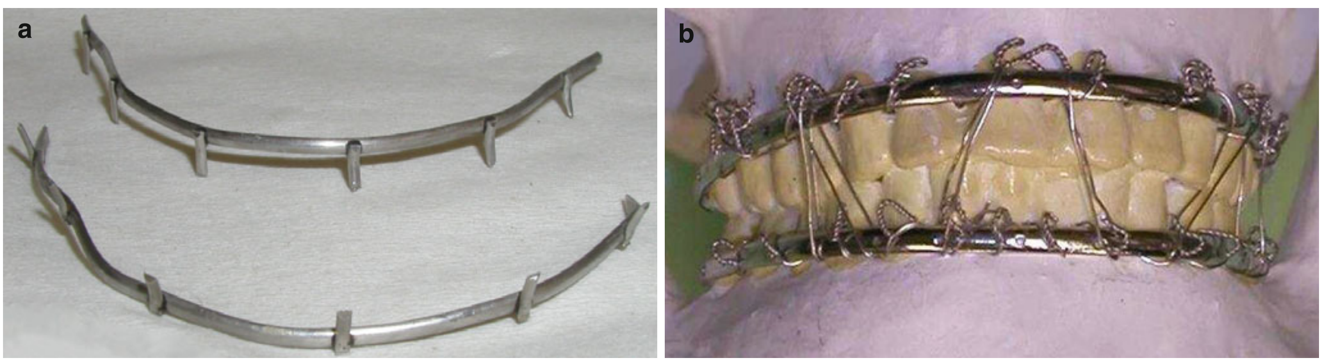

Fig. 3.30 (**a**, **b**) Arch bars

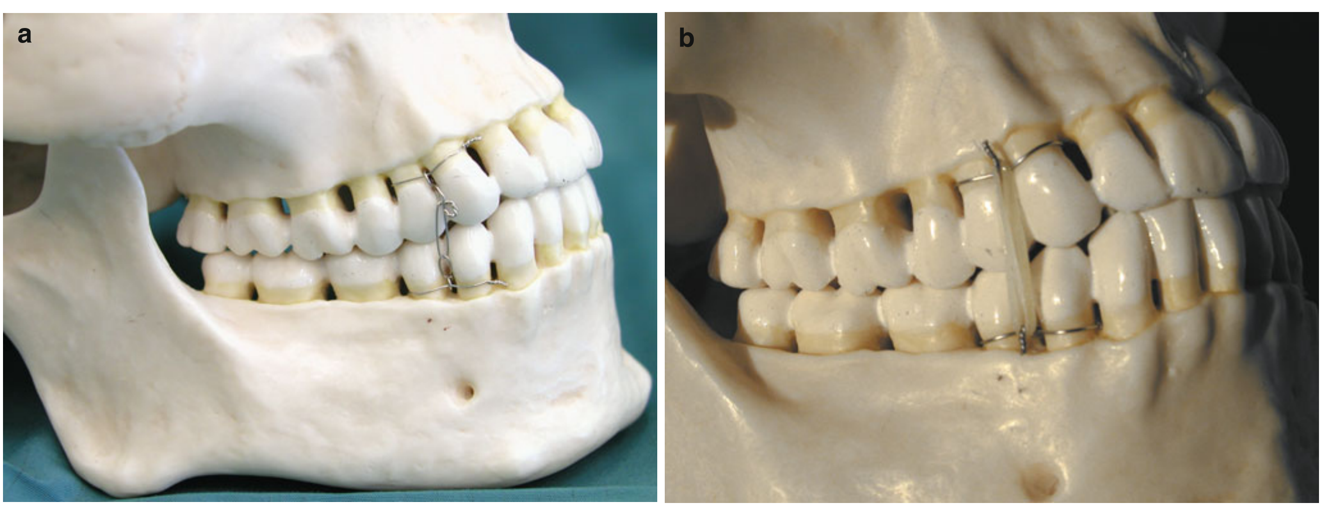

Fig. 3.31 (**a, b**) Tie wires

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4 Principles of Fracture Management

Michael Perry and Simon Holmes

In both orthopaedic and maxillofacial surgery there are a number of basic principles that are commonly shared. This is particularly so in the management of the injured patient (*see* Table 4.1). Over the years, both specialties have moved towards a tendency to surgically expose, anatomically reduce, and then repair fractures (open reduction and internal fixation [ORIF]), in preference to the traditional and less precise methods of "closed" reduction.

However, despite these converging philosophies, there are also some noteworthy differences in the management of fractures of the face and limbs (*see* Table 4.2 and Figs. 4.1, 4.2 and 4.3).

Table 4.1 Shared principles in orthopaedic and maxillofacial trauma

General
Advanced Trauma Life Support™ principles
Multidisciplinary care
Fracture related
Reduction, immobilization, and subsequent restoration of function
General move towards internal fixation in many fractures
Indications for external fixation
The relationship between excessive movement, poor union, and infection
Management of soft tissues
Importance of the soft tissues in the success of fracture healing
Importance of debridement, infection prevention, and maintaining vascularity

Table 4.2 Divergences in orthopaedic and maxillofacial trauma principles

Repair of maxillofacial injuries can generally wait longer than limb injuries
Salivary growth factors and the excellent blood supply to the face provide favorable conditions for healing. Fractures can therefore be more extensively exposed, with less risk of infection or avascular necrosis. Complete detachment of bone from the soft tissues (extracorporeal repair) and nonvascularised bone grafting are also possible (*see* Figs. 4.1, 4.2 and 4.3)
Rigid fixation is not as critical in the face
The repair of facial fractures by necessity requires a higher level of precision
Infected fractures can be plated

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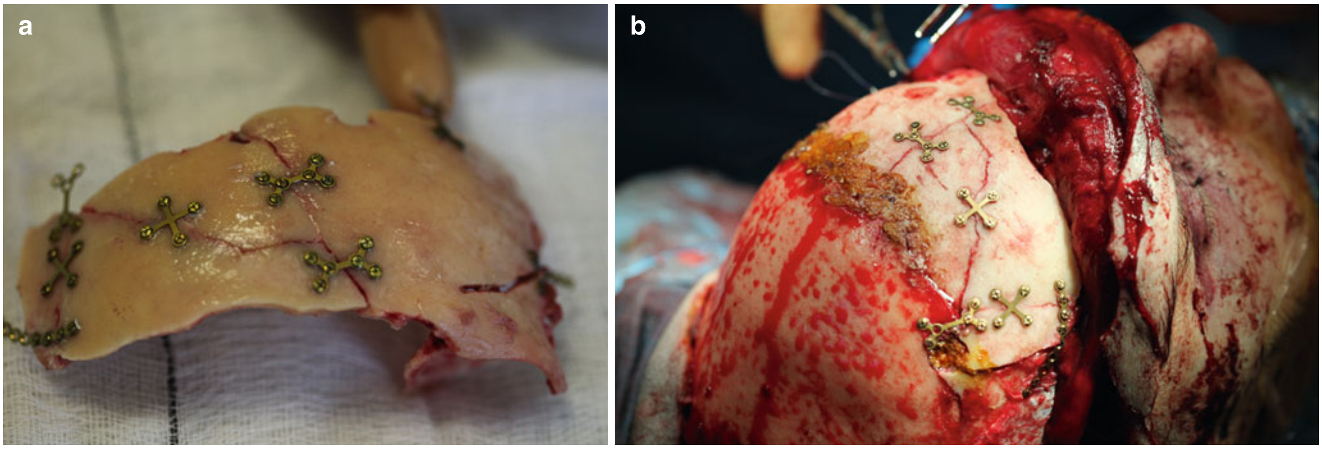

Fig. 4.1 Despite complete detachment from the soft tissues, these fragments can be repaired and returned to the patient, with a very good chance of revascularization and healing (**a**, **b**). Note the bone graft placed over the burr holes. This was harvested from the craniotome slurry during the craniotomy

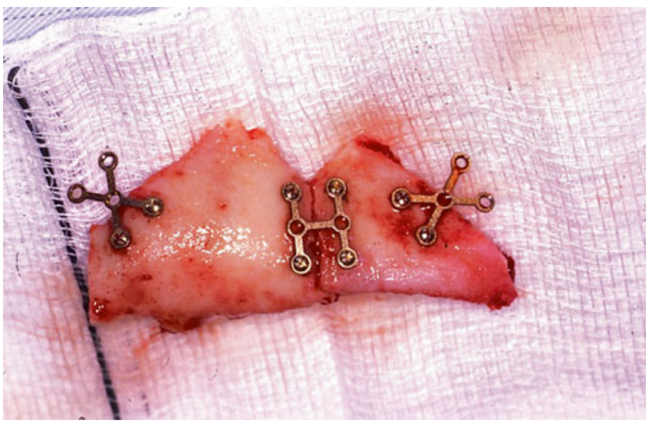

Fig. 4.2 Frontal sinus extracorporeal repair

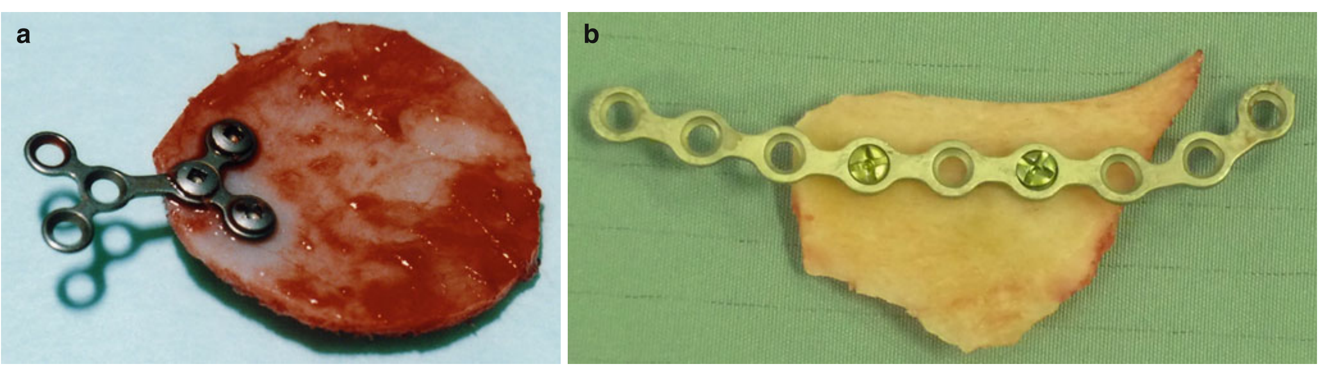

Fig. 4.3 Iliac crest (**a**) and mandibular buccal cortical bone (**b**). Both were successfully used as “free” bone grafts (orbit and zygomatic buttress in these cases)

4.1 Understanding the Healing Process and Using It to Our Advantage

The healing process following fractures to the face (or limbs) can be considered under two subheadings: soft tissues and bone. Soft tissue healing and the management of soft tissue injuries are discussed (not surprisingly) in the chapter on soft tissue injuries. However, many of these management principles are just as important in the management of fractures, especially if they have been openly repaired. It is important to remember that following any impact, the energy that has resulted in the fracture(s) had to pass through the overlying soft tissues in order to get to the bone(s). Together with the additional trauma of any surgical repair, the soft tissues are therefore also damaged to varying extents. Blast, crush, and open injuries are good examples of this. It is not just about getting the bones right (*see* Fig. 4.4).

Whatever the specific type of treatment undertaken, the main aims of fracture management in both orthopaedics and maxillofacial surgery can be summarised as follows:

1. To adequately (or anatomically) reduce the fractures
2. Adequately stabilise them to allow healing
3. Restore preinjury function (and aesthetics in the face)
4. Avoid Complications

These last two points particularly involve optimal care of the soft tissues.

Regarding the first two points, "adequate stability" following repair of facial fractures is not clearly defined in the literature. Similarly, although we may aspire to achieve precise anatomical reduction with all fractures, this is not possible in every fracture, in every case. How important this level of precision is varies depending on the fracture site.

Currently, opinions vary on what is clinically acceptable, when it comes to the level of precision in fracture reduction or the amount of stability that is required for healing. Consequently, a number of treatment options are usually available for most fractures, all of which have been shown to be successful. Perfectly acceptable outcomes can be achieved in patients without true *anatomical* reduction of their fractures, although this does depend on where the fracture is. For some fractures, precision is clearly far more critical than in others (*e.g.*, in medial canthal injuries). Regarding stability, intermaxillary fixation (IMF), semi-rigid fixation and rigid fixation all result in satisfactory healing, yet the degree of stability each produces clearly varies.

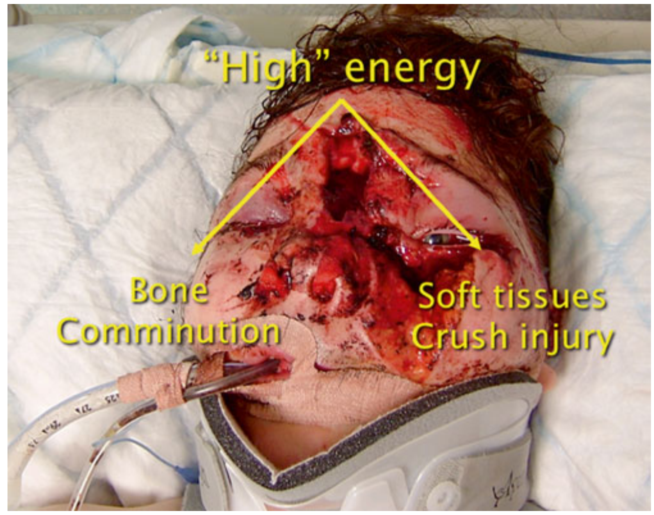

Fig. 4.4 Successful repair requires due consideration to both the hard and soft tissues

In orthopaedic surgery, it is often taught that the success of fracture management depends not only on the condition of the bones and how well they are repaired, but also (and mostly) on the condition of the overlying soft tissues. Consider, for example, two identical fractures, one of which is closed and covered by healthy, well-vascularised soft tissues, while the other is exposed through a heavily contaminated, open wound following a crush injury. Whether the fracture is in the leg, arm, mandible or midface, intuitively outcomes would seem to be better with the first fracture than with the second. This is not the whole story, but does highlight the importance of the soft tissues and in particular the blood supply in the healing process. In this regard the mechanism of injury gives useful clues as to the likelihood of injury to the soft tissues. Comminution in a fracture implies high energy transfer—more energy is also transferred to the surrounding soft tissues in the process of sustaining the fracture. Compare, also, fractures following a single punch, being kicked by a horse, blast injury, and being shot. Each mechanism carries with it increasing amounts of kinetic energy, potentially compromising the vascularity of the surrounding tissues. The worse the blood supply, the greater the chances of infection, nonhealing, and bone loss. Excessive movement across the fracture also has an adverse effect in healing by preventing vascularisation of the bone fragments. The judgement here is, what do we mean by "excessive"? *Micro*movement has been shown to stimulate bony union.

4.2 Terminology

The following terms can sometimes be confusing but they need to be clearly understood (*see* Table 4.3).

4.2.1 Closed and Open Treatments

The term "conservative" is sometimes used to mean treatment that does not involve surgical exposure and therefore implies it is safe. However, this is misleading. "Closed treatment" is a far more appropriate term to use, as this type of treatment is not completely free of risk. For example, intermaxillary fixation poses an obvious risk to the airway and elevation of a zygoma can result in retrobulbar haemorrhage. Closed treatment involves blind manipulation of the bones in an attempt to reduce the fracture. The fracture itself is not visualised and remains covered by its soft tissues—hence the term "closed." The only guides to the accuracy of the reduction are clinical examination, radiographs, or the occlusion. Fracture reduction relies on the fragments fitting back together and not surprisingly anatomical reduction is usually very difficult, particularly if the fracture is comminuted or the overlying periosteum has been torn. Examples of closed reduction include elevation of a fractured zygoma, manipulation of fractured nasal bones, IMF in treatment of mandibular or midface fractures, and using an archbar to stabilise dentoalveolar fractures.

Custom-made cast silver splints, rarely seen today, are another example of closed treatment. Following impression of the upper and lower arches, splints were constructed in two or more parts, each corresponding to one side of the fracture. The splints were then cemented separately onto the upper and lower teeth and IMF slowly applied, resulting in a slow reduction of the fracture. Once reduced, the splints could then be rigidly joined together to provide continued support to the fracture during the healing process (*see* Figs. 4.5, 4.6 and 4.7).

Despite the obvious limitations of closed reduction techniques, this is not obsolete treatment and still has a major role to play in the management of facial fractures.

"Open" treatment ("open reduction") involves the surgical exposure of the fracture, either through the skin or the oral mucosa. This is then anatomically reduced and "internally fixed"; hence the term "open reduction and internal fixation" (ORIF). "Direct" fixation means placing a fixation device (plate, screw, or wire) across or through the fracture. Such fixation can be "rigid" or "semirigid."

Table 4.3 Essential terminology

Closed vs. open treatment
Direct vs. indirect healing
Reduction vs. stabilisation
Rigid vs. semirigid fixation

> Open reduction offers the chance for a more precise reduction and greater support, but exposes the patient to different risks (notably infection).

4.2.2 Direct and Indirect Bone Healing

"Direct" healing (or primary bone healing) is reported to occur when there is absolute stability across a fracture with good bone-to-bone contact. For example, a small hole drilled into bone heals in this way, with immediate growth of bone across the tiny blood-filled gap. Callus formation (which occurs when there is movement across a fracture) is absent. The initial new bone is subsequently remodeled into trabecular bone. Compression across a fracture is said to enable osteoblasts to migrate across the gap from one fragment to the other, laying down bone as they go. Usually this results in rapid healing.

"Indirect" healing is a different process and occurs across a mobile fracture. It is typically seen in limbs treated with plaster casts. It is also the natural healing process seen in land mammals. Initial hematoma formation around the fracture is followed by the ingrowth of delicate fibrovascular tissue. Gradual ossification occurs, with the development of surrounding proliferative osteoid, sometimes referred to as "pre bone," "immature bone," or "callus." This provides early stability for healing to continue. Once fully healed, remodeling of the callus occurs, resulting finally in "mature" trabecular bone. Callus formation thus implies mobility across a fracture.

Fracture healing therefore depends on providing adequate stability, although it does not have to be absolutely rigid. The question is, what is meant by "adequate"? Some movement has been shown to stimulate bone healing, yet if this is excessive, callus formation is limited and fibrous or nonunion occurs. Excessive movement also prevents vascular ingrowth and can predispose to infection.

Fig. 4.5 Cast splints in management of mandibular fracture. Note extension on left to prevent proximal fracture from displacing upwards

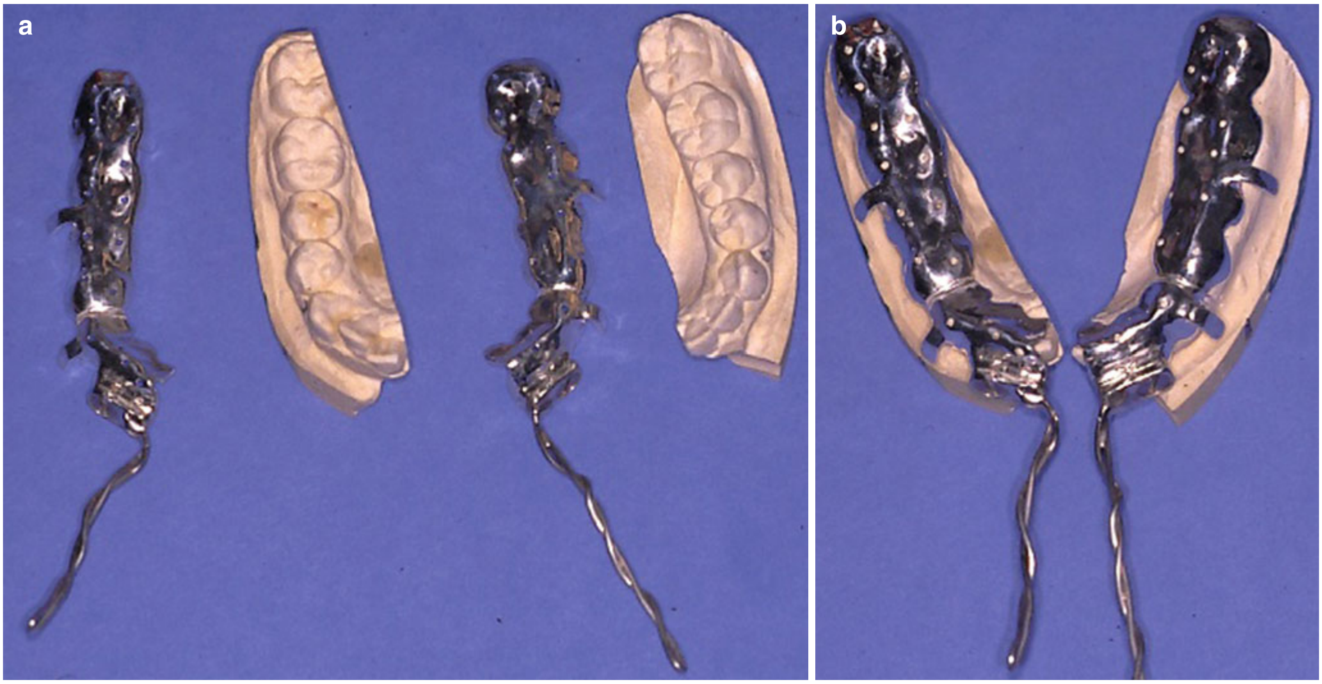

Fig. 4.6 (**a**, **b**) Two-part cast splints for a mandibular fracture

4.2.3 Reduction and Stabilisation

It is important to appreciate the distinction between reduction and stabilisation. One does not guarantee the other. Even the "best" fixation is of little value if the reduction is poor—the bones will simply heal in the wrong position. Similarly, an anatomically reduced fracture will quickly displace if it is not adequately stabilized. This is particularly important in the maxillofacial region, where a well-healed but displaced fracture can result in significant cosmetic disability. Inadequate stability can result in a number of significant problems (*see* Table 4.4).

4.2.4 Rigid and Semirigid Fixation

In the strictest sense, "rigid" fixation means that there is no movement whatsoever across the fracture site. This produces such a level of stability that direct bone healing can take place (so long as there is sufficient bone-to-bone contact). Rigid fixation therefore requires strong "load bearing" fixation devices (usually large plates and bicortical screws) to ensure no movement occurs across the fracture. As such, these devices tend to be bulky. Some plates are designed to apply an initial compressive force across the fracture, to encourage direct healing. However, this force drops off sharply with time due to bone resorption at the fracture site. In the maxillofacial region, compression is only possible in the mandible. The other bones of the face are too friable to support such bulky plates and heavy forces.

Fig. 4.7 Splints *in situ* using upper dentition for support

Table 4.4 Possible consequences of inadequate stability across a fracture

Infection
Malunion, fibrous, or nonunion
Excess callus formation

"Semi-rigid" fixation, as the name implies, is where fixation across a fracture is sufficient for it to heal, although a variable amount of "micromovement" occurs. This is more in keeping with biological healing. Much smaller "miniplates" can therefore be used, avoiding the need for bulky plates. However, this distinction between rigid and semirigid fixation techniques is now becoming less critical. Some of the newer miniplates currently available are now beginning to provide degrees of stability, which are effectively "rigid" fixation (*see* Fig. 4.8).

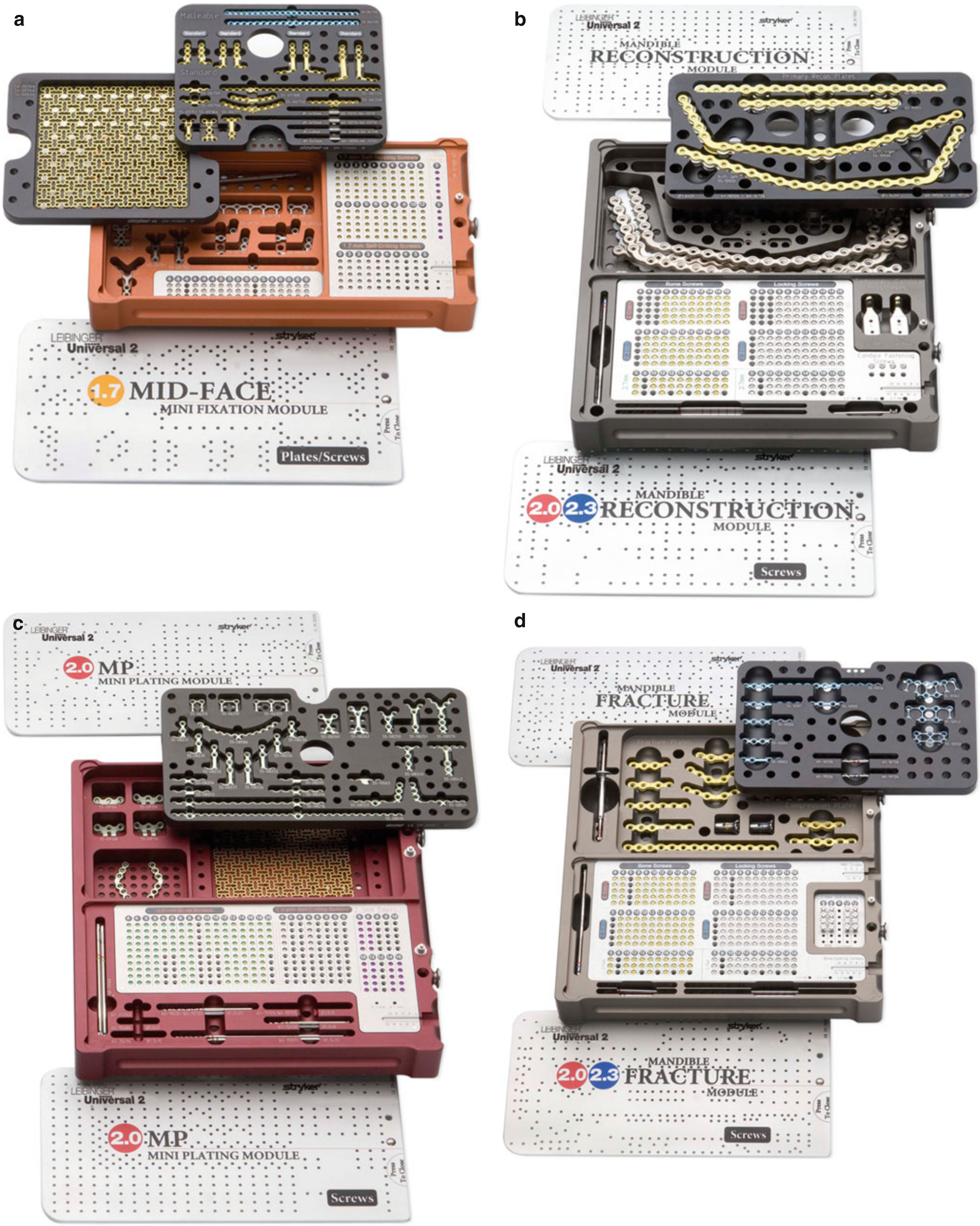

Fig. 4.8 (**a**–**d**) Plating set. These are now widely available. Many kits exist and the choice can be somewhat bewildering

4.3 Some Fixation Techniques

4.3.1 Semirigid Fixation in the Mandible

Semirigid fixation is now commonly used to repair simple mandibular fractures in many centers. This requires a good understanding of what is (and what is not) acceptable stability during the healing process. It also requires knowledge of the "lines of tension" that occur across the fracture site(s). These have been comprehensively described in the literature but are summarised as follows.

When a bone breaks (and the fracture ends are still in contact with each other), displacing forces acting on the fragments sets up "zones" of compression and tension across the fracture. Any plate secured along an area of tension effectively converts these fracture-separating forces into compressive ones. These forces are mostly generated by the surrounding attached muscles. Like a suspension bridge, heavy loads can be supported by relatively small structures. Since compressive forces are not generated by the plate itself, smaller plates and "monocortical" screws can be used to secure it to the outer cortical bone alone. Consequently there is greater flexibility in where the plate can be placed. Theoretically screws can be placed safely over dental roots and the inferior alveolar nerve, so long as care is taken during drilling and the screw is not too long.

In the mandible, the lines of tension are often referred to as "Champy's lines." These are only applicable to simple fractures. Comminuted fractures cannot be managed solely on these principles (*see* Fig. 4.9).

Posteriorly there is one line, but anteriorly (to the premolars) this splits into two. This is because of the complex muscle attachments (genial, digastic, and mylohyoid) and the curvature of the bone, which together result in torsional forces. For this reason two miniplates are necessary for "anterior" fractures (symphysis and parasymphysis), while only one is required for "posterior" fractures.

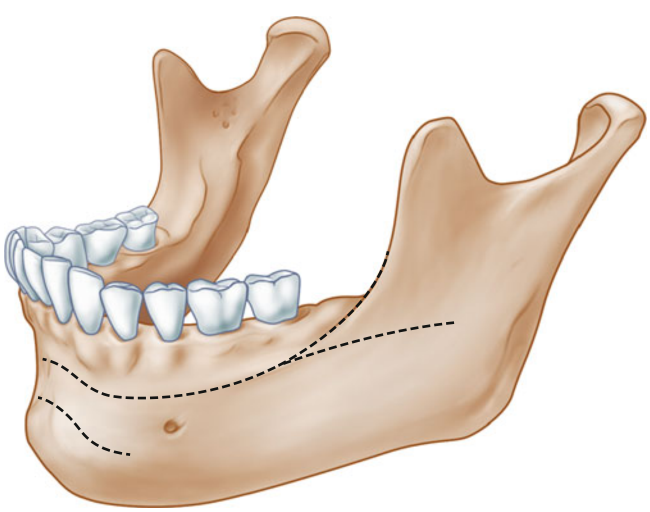

Fig. 4.9 Champy's lines

The miniplate technique works well for most simple mandibular fractures. However, when fractures are comminuted or oblique (where the abutting fragments can "slip" past each other) the technique needs to be modified. In these fractures, zones of tension cannot be easily converted to compression, and displacement is more likely. Although compression is not a requirement, adequate stability still is. Multiple plates or postoperative IMF are therefore required.

4.3.2 Semirigid Fixation at Other Sites

For the rest of the craniofacial skeleton, lines of compression and tension are not clearly defined. Plates and screws at these sites rely more on their intrinsic strength rather than any compressive forces they may generate. As materials have become stronger, so plates have become smaller. The use of microplates for internal fixation in some fractures is now commonly undertaken. These tend to be used at non–load-bearing sites, where the bone is very thin and/or covered by a thin layer of soft tissues. Microplates are now commonly used in the repair of nasoethmoidal fractures, nasomaxillary fractures, and frontal sinus repair.

Resorbable materials are also now widely available and commonly used in both trauma and orthognathic surgery. However, these lack the same intrinsic strength as titanium and therefore cannot be used to carry heavy loads. For semirigid fixation, the choice between titanium and resorbable materials is a matter of personal preference. Each has advantages and disadvantages (*see* Figs. 4.10 and 4.11).

4.3.3 Lag Screws

This is a relatively simple technique, sometimes regarded as a compromise between rigid and semirigid fixation. It is sometimes used when obliquely orientated fractures overlap (*i.e.*, the fracture line is not perpendicular to the surface of the bone), or for securing bone grafts. In order to provide the necessary compression there must be sufficiently thick bone on both sides of the fracture (commonly seen in the mandible).

In principle, a screw hole is drilled perpendicular to the fracture line (not necessarily the surface of the bone), effectively "kebabbing" both bone fragments. The screw is then passed while the fracture is anatomically reduced. Either by design of the screw, or by overdrilling the proximal hole (in the fragment closest to the screw head), only the distal fragment is engaged by the thread of the screw. This allows the fragments to be compressed on tightening. Care is required as overtightening can split small fragments (a "single-hole plate" can sometimes be used as a washer which

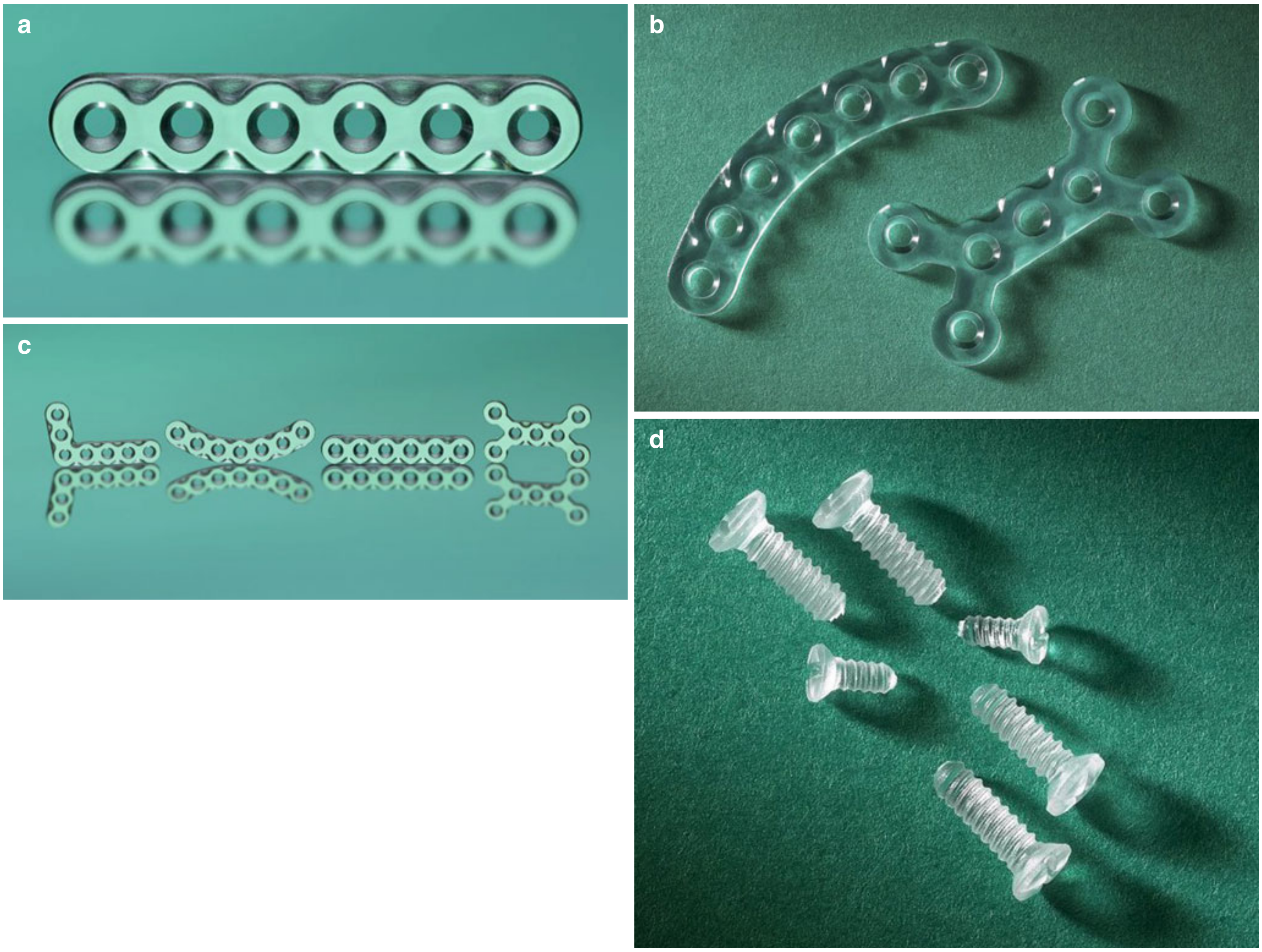

Fig. 4.10 (**a–d**) Resorbable materials are now available. These are not yet strong enough to resist heavy loads, but can be used in most fractures. Like all other materials they are not totally immune to complications

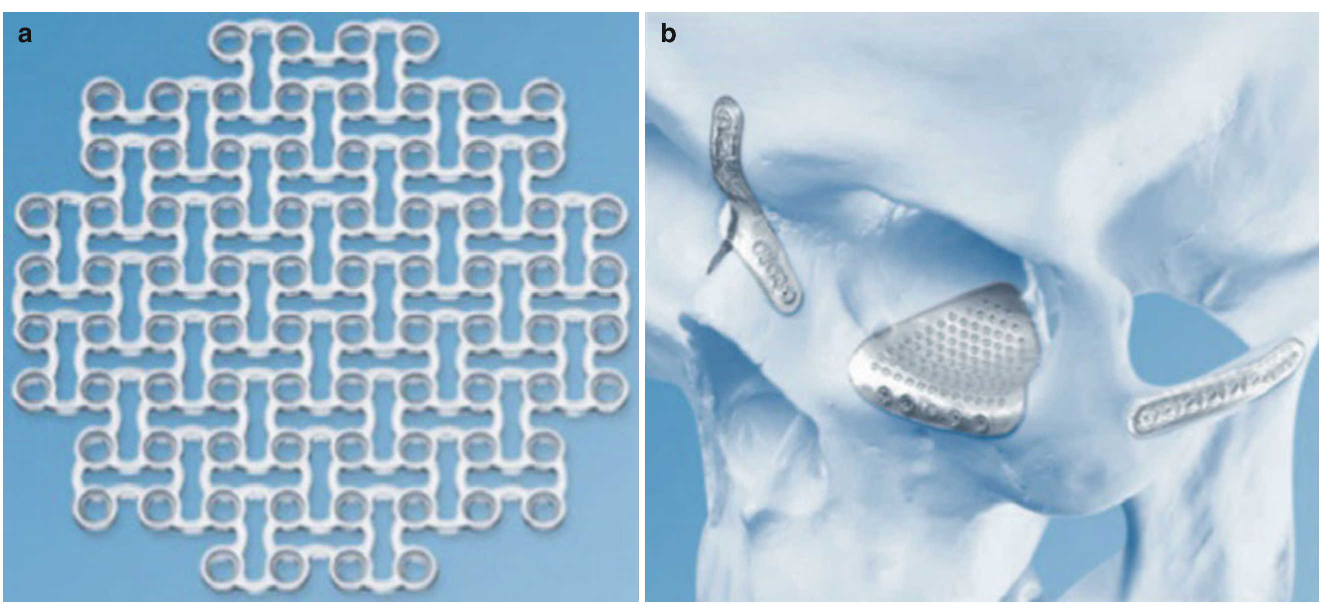

Fig. 4.11 Meshlike materials provide wider scope for support and screw placement (**a**, **b**)

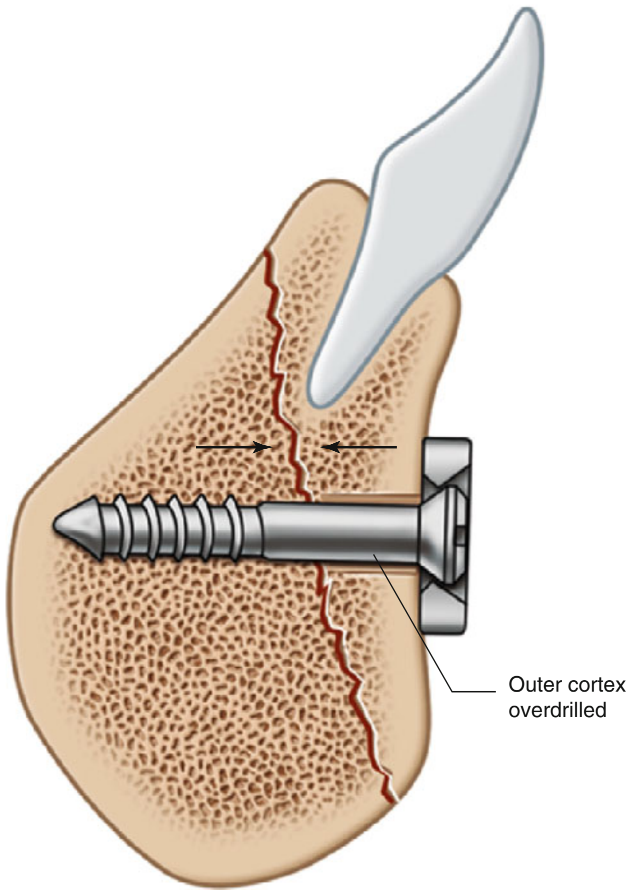

Fig. 4.12 Lag screw principle. Note the proximal fragment (nearest the screw head) does not engage the screw. This allows compression. If the screw engages both fragments, it is called a "positional screw"

helps spread forces across the surface of the fragment). Varying combinations of this technique are possible, using multiple screws, or plates and lag screws. When used effectively, lag screws offer excellent reduction and near rigid fixation due to compression. Lag screw fixation of fractures involving the posterior mandible and ramus is possible, but is more technically demanding. Often, a percutaneous trocar technique is necessary to place the screw without damaging the inferior alveolar nerve or teeth. This technique offers a quick and precise method of reduction in selected cases (*see* Figs. 4.12–4.17).

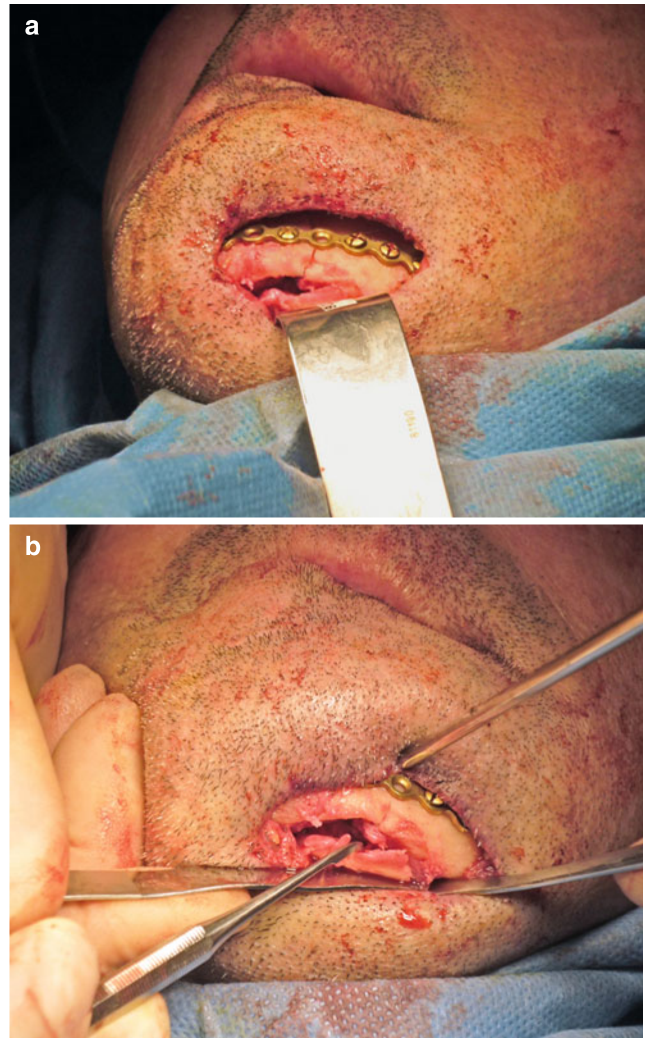

Fig. 4.13 Lag screw of anterior mandible. Access is through an overlaying laceration (**a**). Initial dissection reveals a comminuted fracture with large segment of lower border (**b**)

Fig. 4.14 Segment was large enough to support a compression (lag) screw. Good reduction was possible

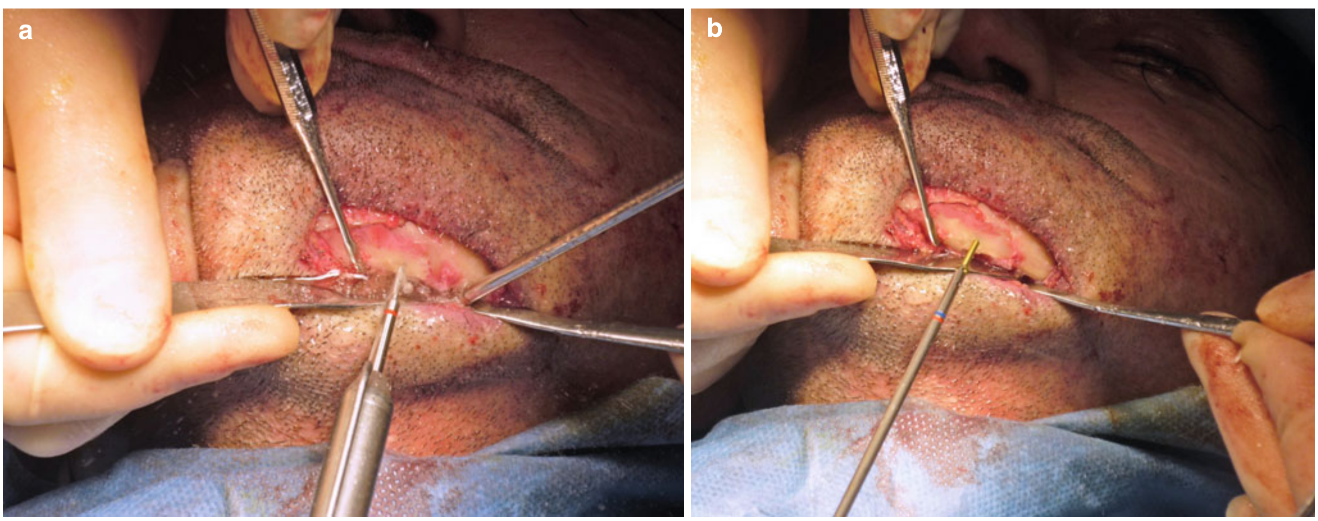

Fig. 4.15 With the segment in place, a hole was drilled and the screw placed (**a**). The proximal hole was overdrilled to allow compression (**b**)

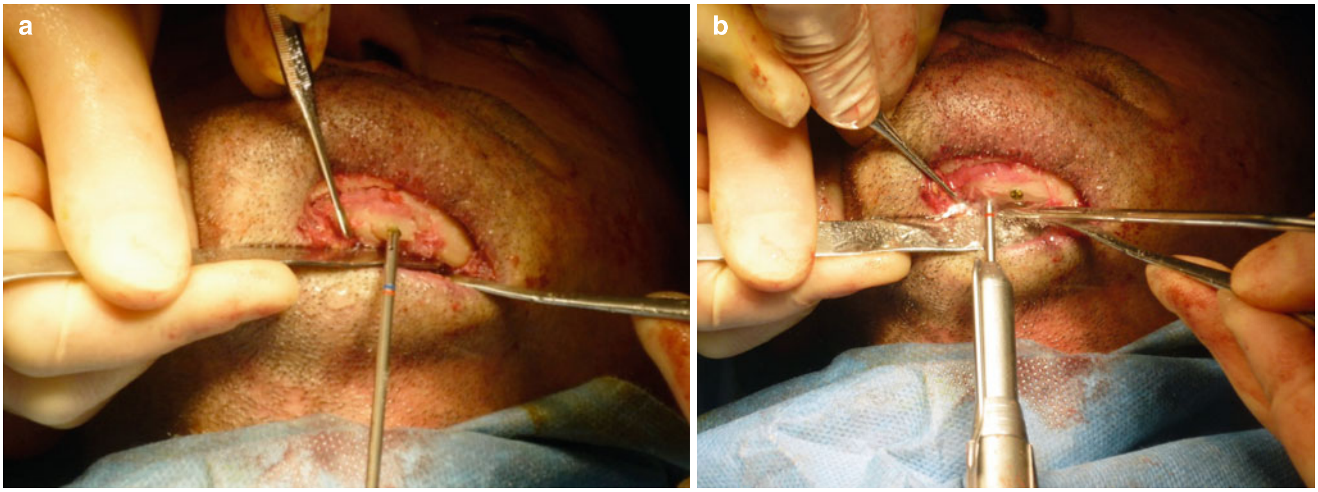

Fig. 4.16 The screw was tightened and a second hole drilled (**a**). Ideally two screws should be used to prevent rotation of the fragment (**b**), but this is not always possible

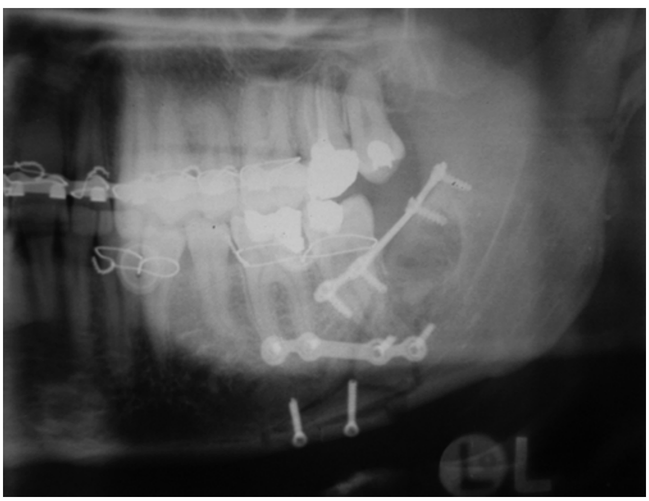

Fig. 4.17 Postoperative appearance (another case)

4.4 Choosing which Method of Fixation

In many fractures the choice between "open" and "closed" reduction is often straightforward. There are also many other fractures where both are equally acceptable. Sometimes a compromise is required—for instance in patients too unstable for a general anesthetic. IMF placed under local anaesthesia may then be used to treat minimally displaced fractures very effectively.

The choice between rigid and semi-rigid fixation in mandibular fractures can sometimes be difficult (*see* Table 4.5). This is because of the debate over the question "How rigid does fixation need to be?" IMF, for example, certainly does not rigidly immobilise fractures, yet it clearly works and they heal—even if not anatomically. Those surgeons who advocate the use of two or more plates across a fracture, or the use of larger (2.3–2.7-mm) plates, argue that this is necessary in order to adequately stabilize it. On the other hand, others argue that this is far too excessive and that smaller plates provide sufficient fixation, particularly since they are now made from stronger materials. These have the advantage of requiring less soft tissue dissection and potentially fewer complications.

In many cases there is no "black and white" answer and many options exist (*see* Table 4.6). Each case needs to be weighed up carefully, taking into accounts the pros and cons of each option, often tempered with one's own personal experiences (*see* Figs. 4.18–4.33).

Table 4.5 Rigid vs. semi-rigid fixation

Rigid	Semi-rigid
Large, strong plates	Small, malleable plates
Require extraoral incision	Can be placed through the mouth
Risk to dental roots and ID nerve	Less risk to roots and nerve
Immediate return to function	Still requires minimal load bearing
Risk of stress shielding	No stress shielding
Can delay healing	Micromovement stimulates healing
Need to be removed	Can be left *in situ*
Less risk of infection	Can get infected
Unforgiving technique	Can be "fine tuned" with elastic IMF
Can only be used in the mandible	Can be used most of face
Good results in comminuted fractures	Variable results in comminuted fractures
Can support block bone grafts	Less support for grafts
Long procedure	Often quick procedure
Compromise periosteal vascularity	Less devascularisation

Table 4.6 Treatment options in fractures

No active treatment. Avoid displacing forces (notably heavy chewing)
Closed treatment:
Manipulation of fracture and external support (*e.g.*, plaster)
Manipulation of fracture and external fixation
Open treatment (direct visualisation of the fracture through wound or incision)
Then close wound and external support
Then close wound and external fixation
Semirigid internal fixation
Rigid internal fixation

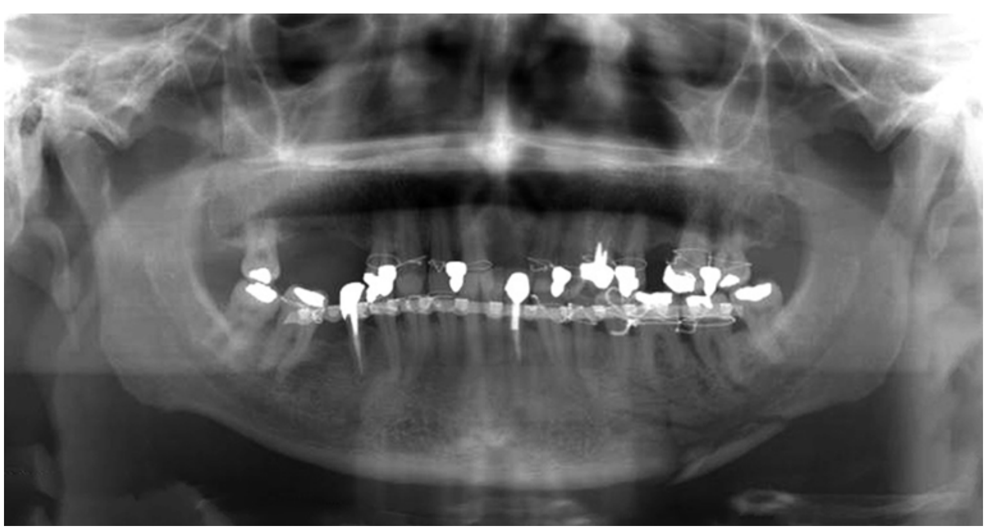

Fig. 4.18 Comminuted mandibular fracture. How would you manage this? (IMF, semirigid, rigid, or external fixation?) Each has advantages and disadvantages. Remember the soft tissues when planning

4.5 Applying Rigid Fixation

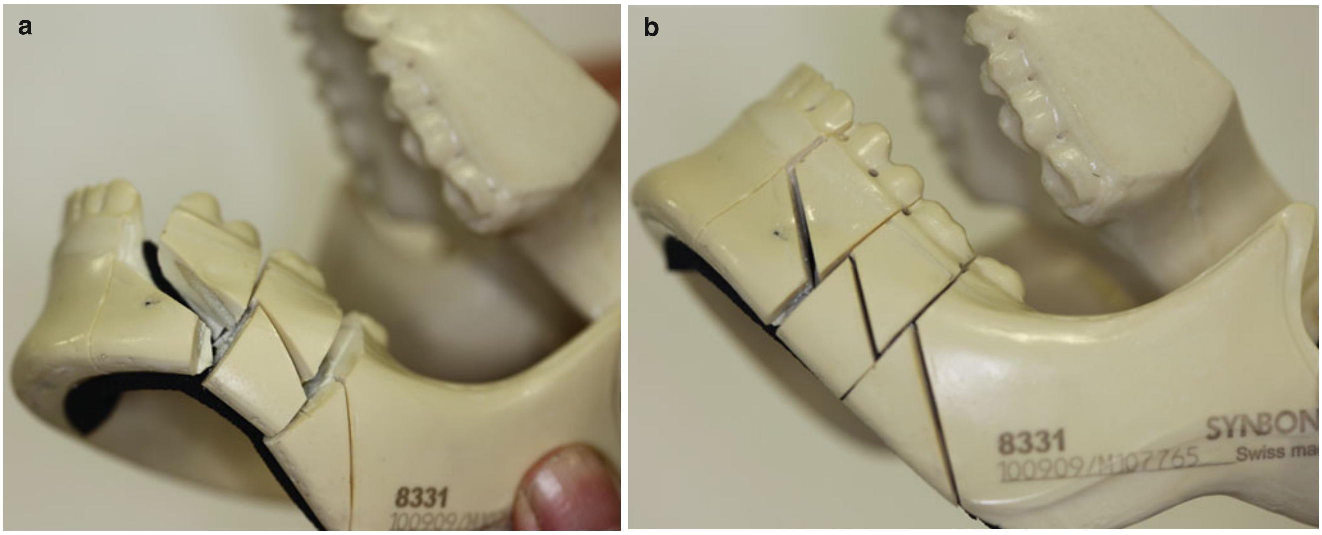

Fig. 4.19 Rigid fixation. (**a**, **b**) This is an unforgiving technique but very useful in the repair of comminuted mandibular fractures. It requires an extraoral incision. Variation in the following steps is possible

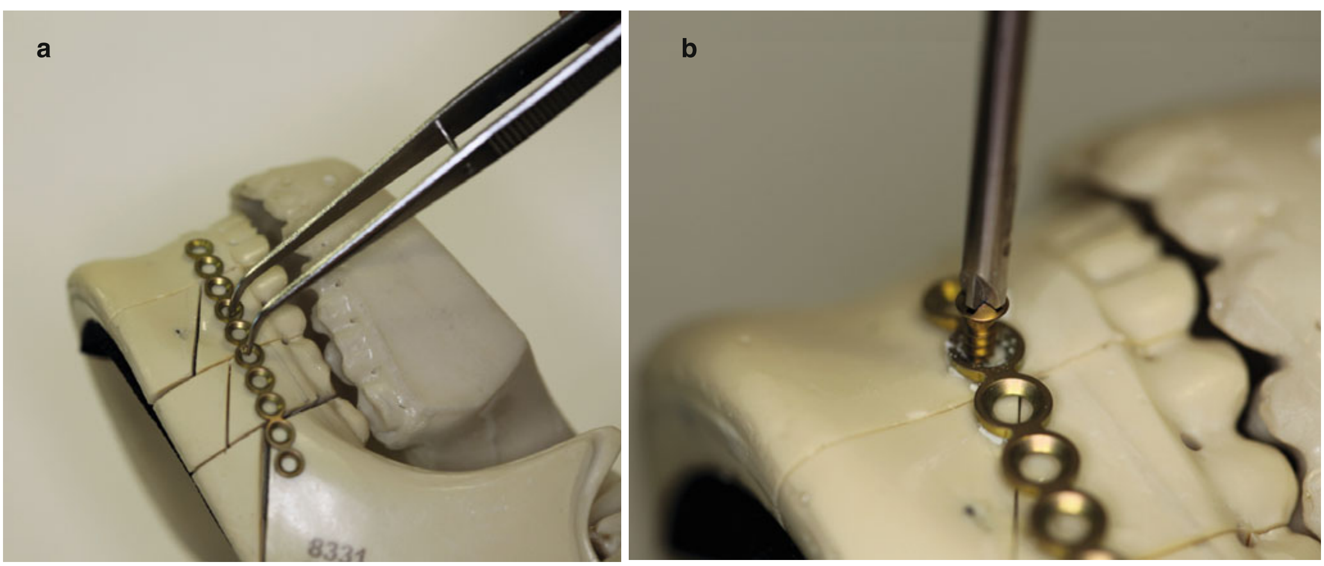

Fig. 4.20 The aim is to reduce and bridge the fractures with a precisely shaped load-bearing plate along the lower border. Supplemental fixation may be necessary depending on the fractures. The fractures are initially reduced (with IMF) and the upper fractures reduced and stabilised using conventional adaptive plates (**a**, **b**)

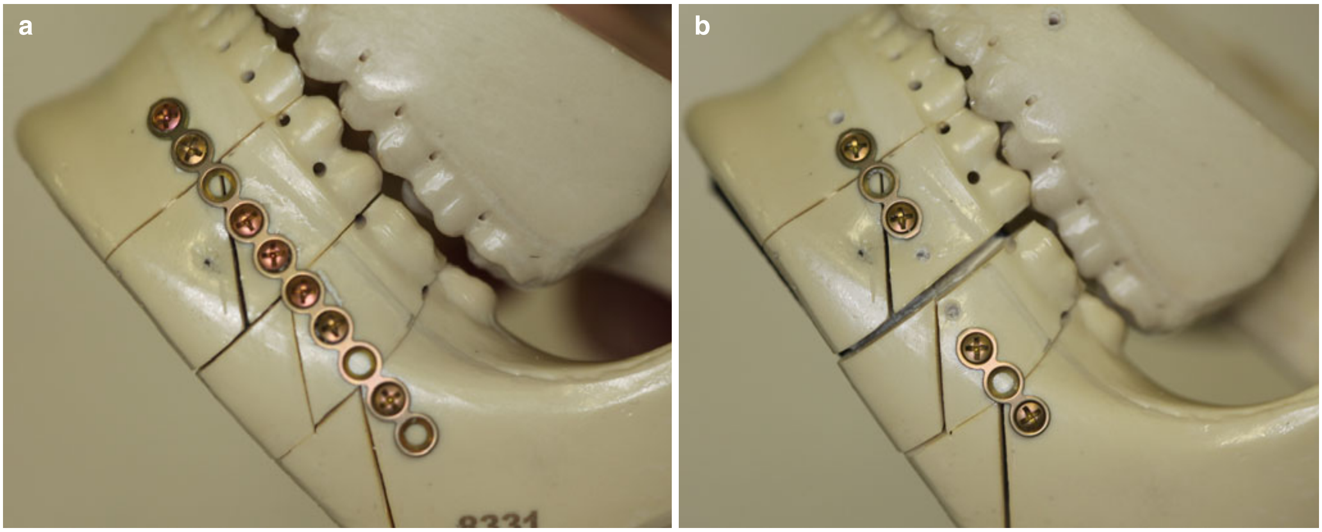

Fig. 4.21 Upper reduction can be achieved with one or multiple plates (**a**, **b**). This makes manipulation of the overall fracture site easier

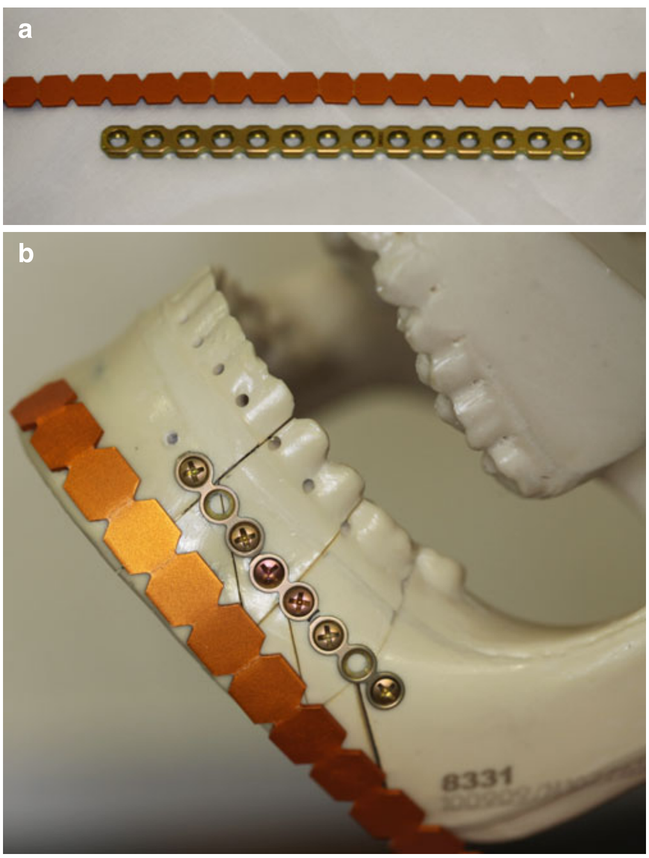

Fig. 4.22 Bending load-bearing plates (**a**) is not easy if you don't use them regularly. They have to fit precisely. These come in several sizes (2.3, 2.7 mm) and require special equipment to adapt them. A malleable template can be used to determine the contour. The plate is then adapted to that (**b**)

Fig. 4.23 Contoured plate (**a**) and drill guide (**b**)

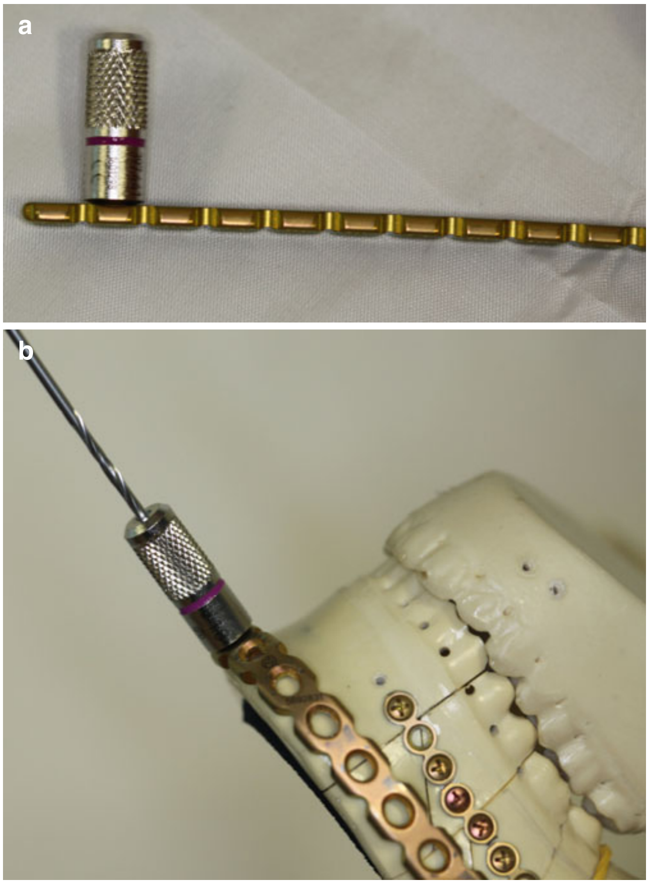

Fig. 4.24 Drill guides are necessary to allow precise and rigid placement of the screws (**a**). This guide screws into the hole in the plate (**b**). Others need to be hand-held

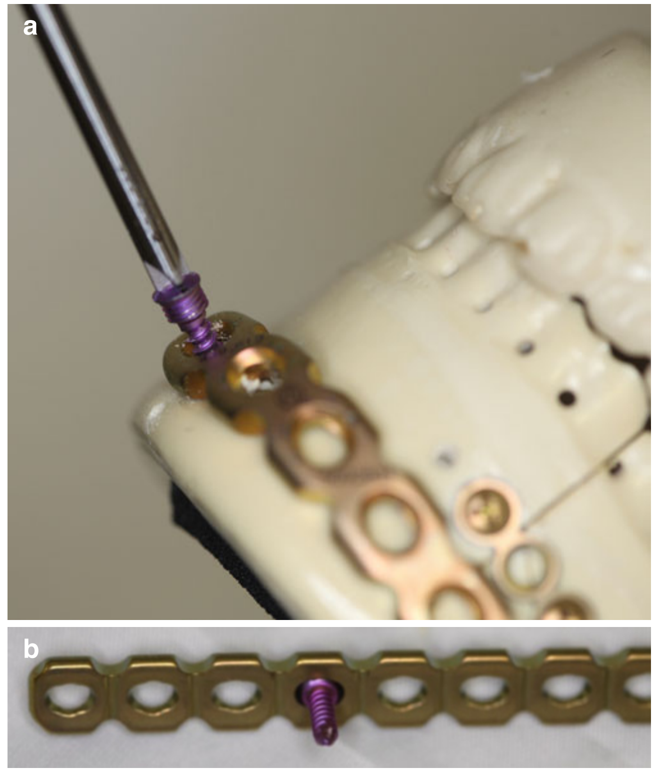

Fig. 4.25 After the hole is drilled, its depth is measured with a depth gauge and a bicortical screw is placed (**a**). Some screws are threaded just under the head to engage the thread in the plate. These are called “locking” plates (**b**)

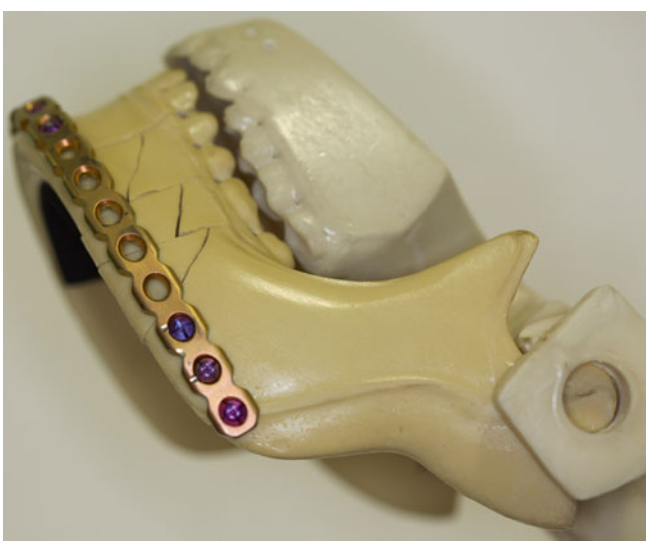

Fig. 4.26 Lower border locking plate *in situ*. If not contoured precisely, anatomical reduction will be impossible

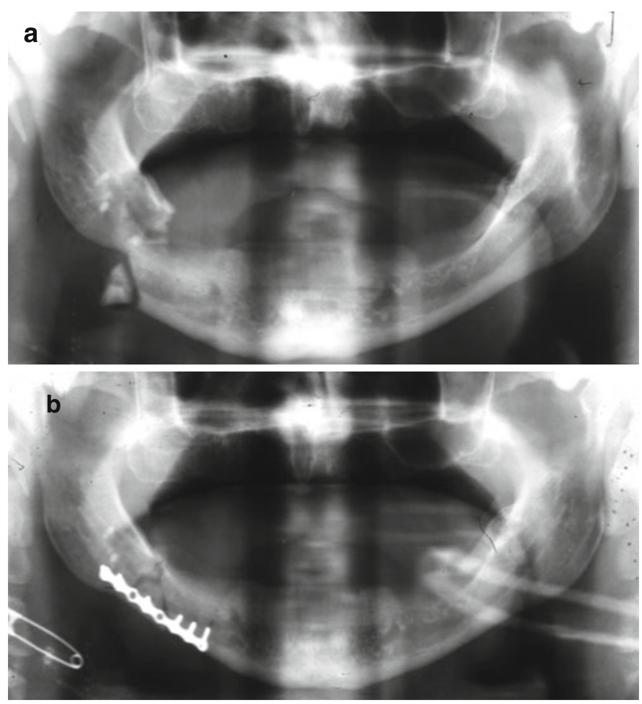

Fig. 4.27 Rigid fixation using a nonlocking plate (**a**, **b**)

4.6 Applying Semirigid Fixation (Miniplates)

4.6.1 Posterior (Angle/Body) Fractures

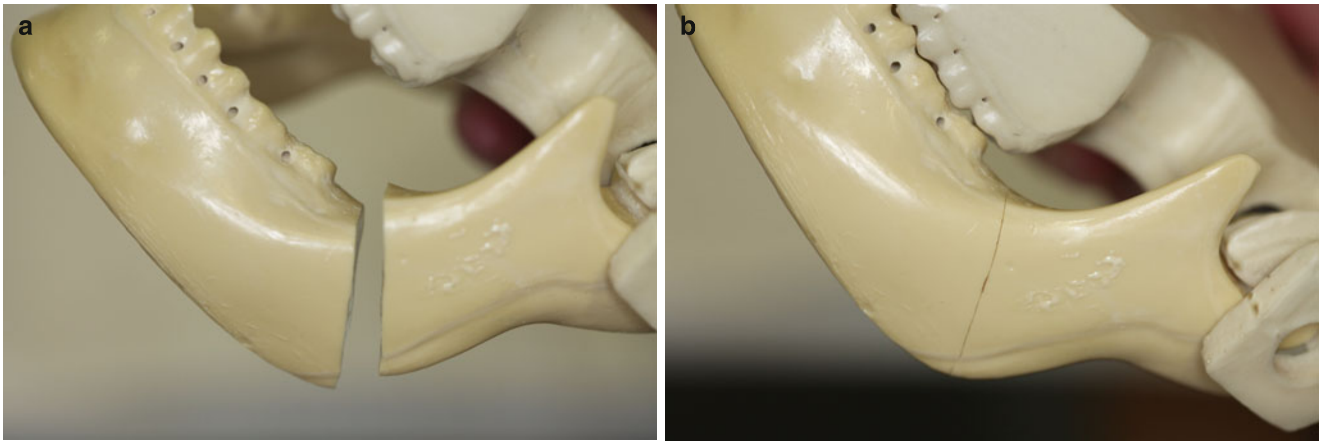

Fig. 4.28 Most repairs are undertaken through the mouth. The fracture is anatomically reduced either with IMF or a hand-held reduction (**a**, **b**)

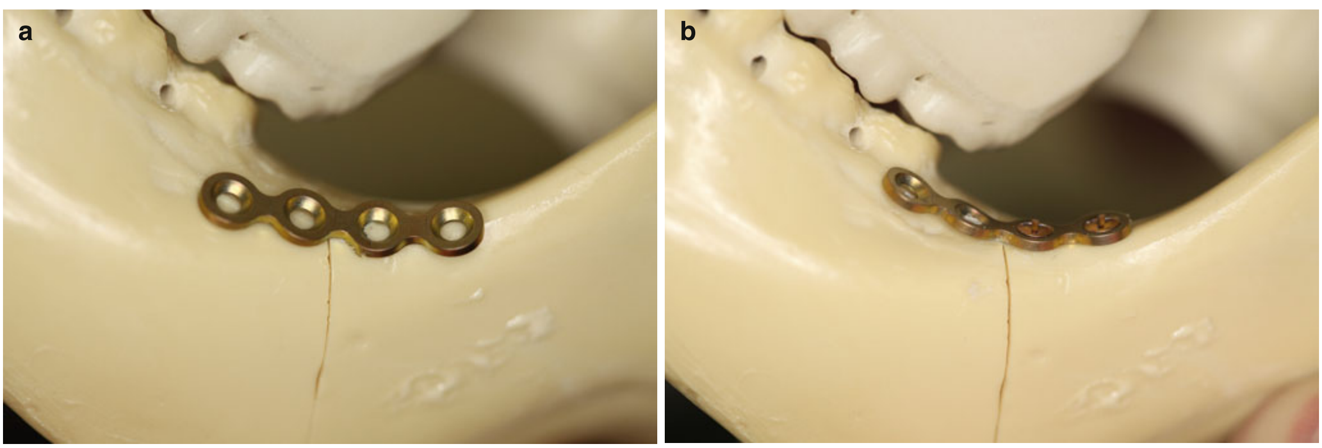

Fig. 4.29 The miniplate is adapted to "Champy's line" (*see* text). These can be bent with forceps or sometimes by hand—the plates are not very strong (**a**, **b**)

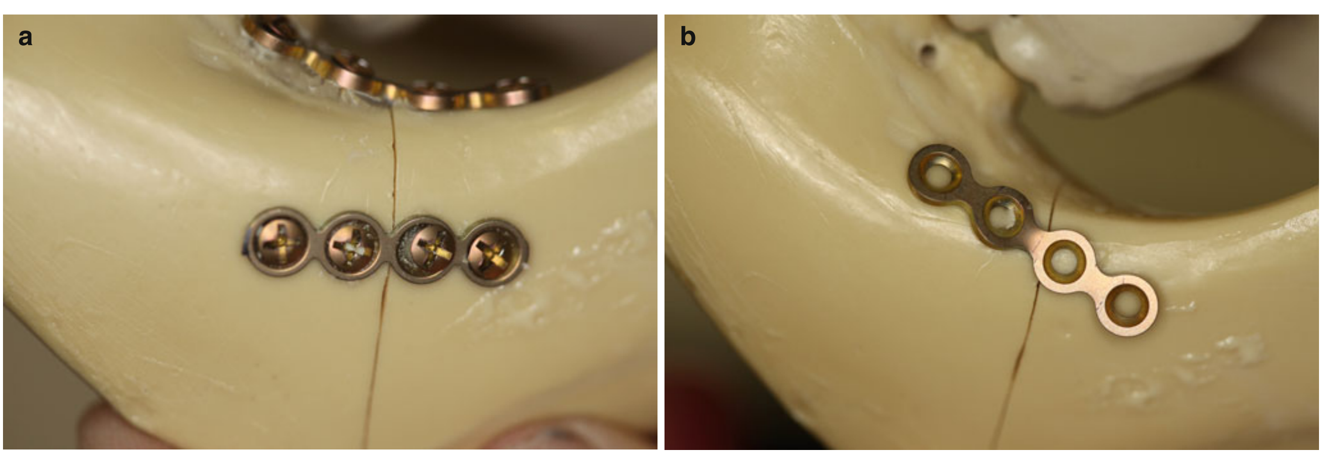

Fig. 4.30 Variations are common. Here are shown two plates: (**a**) Transbuccal technique; and (**b**) "Propeller twist." Both are acceptable alternatives

4.6.2 Anterior (Symphyseal/Parasymphyseal) Fractures

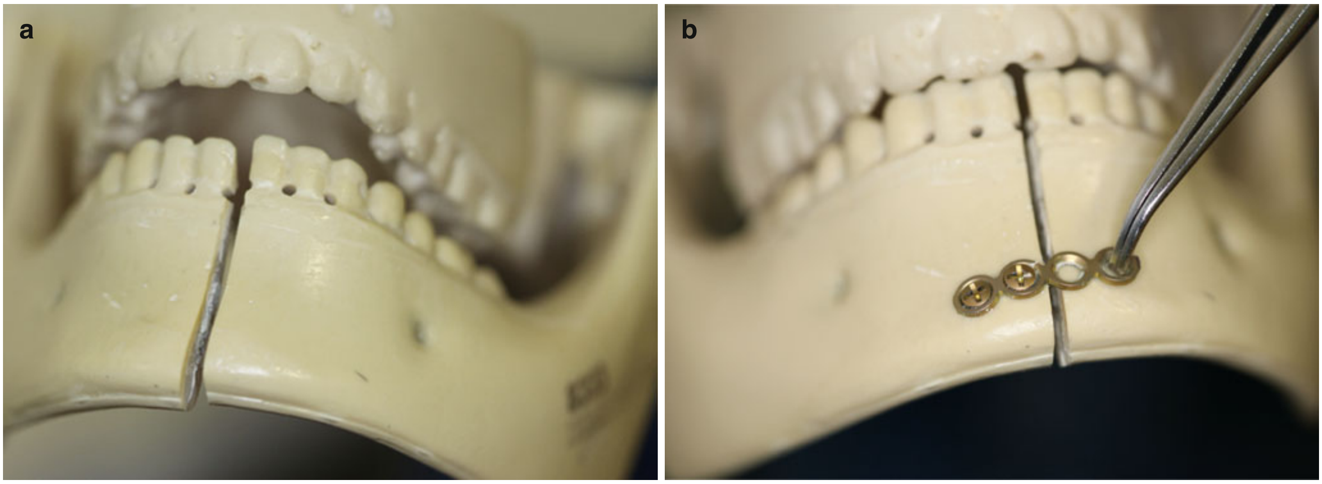

Fig. 4.31 Most repairs are undertaken through the mouth. A plate is adapted and screwed to one side of the fracture (**a**, **b**)

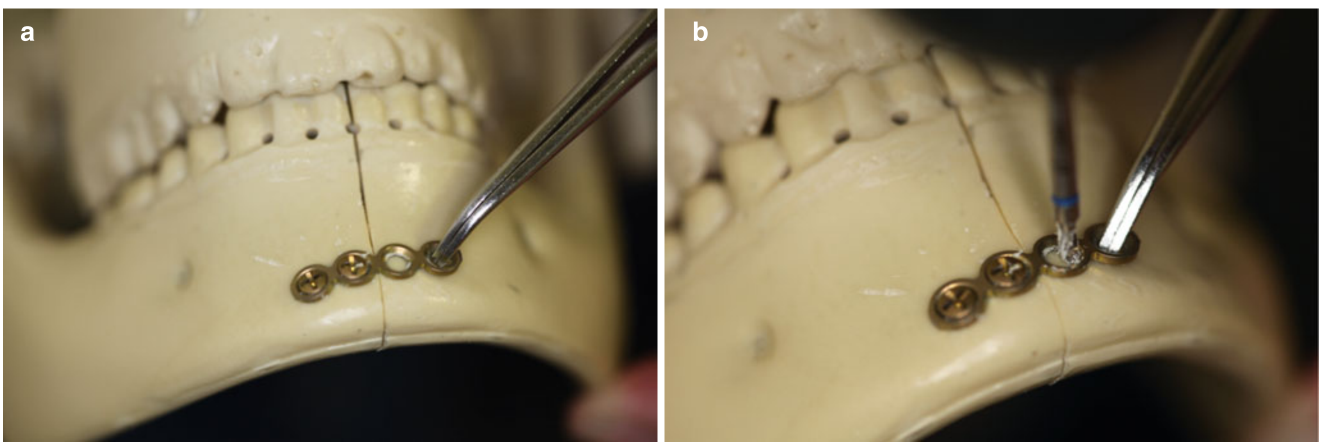

Fig. 4.32 The fracture is anatomically reduced and the remaining screws placed (**a**, **b**)

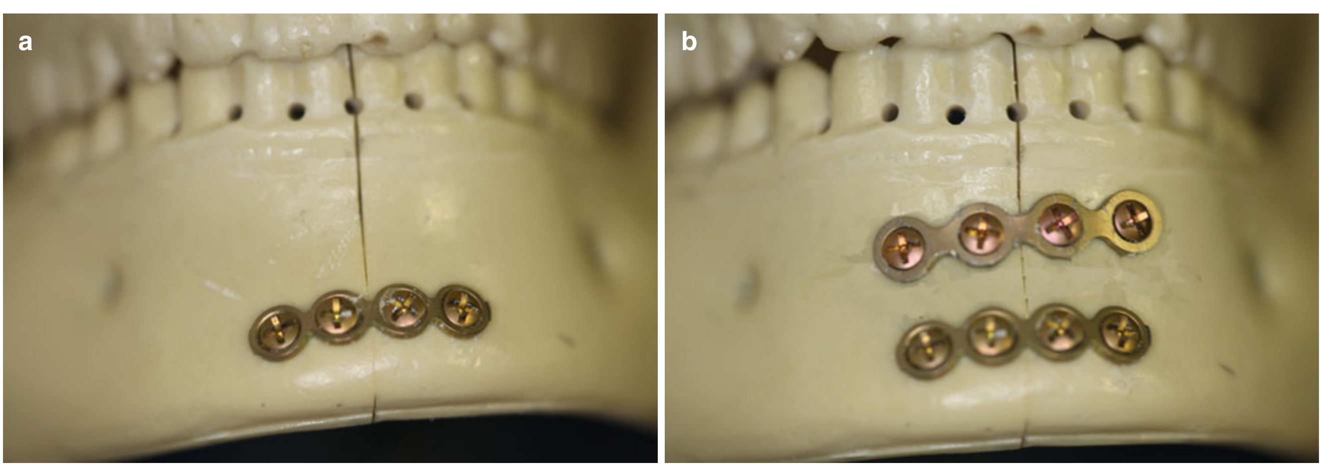

Fig. 4.33 Following this a second plate is positioned to resist torsional forces. The further these plates are apart, the better the mechanical advantage (**a**, **b**)

4.7 External Fixation

With the development of newer, stronger, and more biocompatible materials used for internal fixation, many of the traditional indications for external fixation no longer apply in many patients. Infected fractures, once an absolute contraindication to internal fixation, can now be managed with internal fixation, so long as rigidity across the fracture site can be achieved. It is the combination of infection *and movement* that predisposes fractures to osteomyelitis. If rigidity can be achieved, vascularity to the infected site can be improved sufficiently to resolve it. Similarly, continuity defects can be supported by internal bridging plates and comminuted fractures can be adequately stabilised using smaller internal fixation plates, rather than external fixators. Nevertheless, external fixation still plays an important role in selected cases and knowledge of its techniques is still worthwhile (*see* Fig. 4.34).

The principle of external fixation is very simple. Fixation pins (ideally at least two) are placed either side of the fracture or defect. If the fracture is comminuted, additional pins can be placed in the central fragments, if these are large enough to support them. The fracture is then reduced (or aligned) and the pins are then stabilised using an external framework. This is not rigid fixation but can produce a significant degree of rigidity across the fracture (*see* Fig. 4.35).

Historically, several configurations of external fixation were commonly used (*see* Fig. 4.36).

With midface fractures, external fixators provide a means of reducing and stabilising the dental arches and adjacent bones. Initial methods used cast silver cap splints, but these were later changed to upper arch bars. These splints were connected by a system of rods to a noninjured part of the head or face, usually the skull. Common methods included the halo frame, which was secured to the skull. This very stable device was initially developed for the treatment of cervical spine injuries. If necessary the mandible can also "pinned" externally with a "box frame" configuration.

One advantage of external fixation is that it can be used to provide anterior traction to the midface, aiding reduction without the need for general anaesthesia. But this is rarely required nowadays. Similarly it can be used

Fig. 4.34 External fixation still has a role in trauma

to adjust the vertical facial height in patients with complex injuries (*e.g.*, widespread comminution with bilateral condylar neck fractures). If necessary the cranial attachment may be repositioned more posteriorly (if a craniotomy is required). Numerous designs are possible as pin sites can be "tailored" to each case. So long as a few principles are followed, a fair degree of flexibility is possible (*see* Table 4.7). These techniques are now mostly of historical interest.

Alternatively, smaller external fixators can be placed across some fractures—this is most suited to the mandible or zygoma. Fixators placed directly across fractures have several advantages. They can be quickly applied with minimal exposure and stripping of the periosteum from the bone. In order to obtain effective stability, two pins are usually required on either side of the fracture. The position of the bones can also be adjusted (often without general anaesthesia) if postoperative radiographs shows inadequate reduction. In specific cases, fixators can be used to provide a degree of callus distraction or "bone transport."

Currently the main role of external fixation in maxillofacial trauma is to provide rapid "first aid" stabilization (damage control) in the multiply injured patient. Or where there are limited facilities, some stability prior to transfer to a definitive care center. With gunshot wounds or other types of contamination, this method also provides good "long-term" temporary fixation, until the contaminated wounds have healed. External fixators are also particularly useful in maintaining space and orientation in continuity defects (*see* Fig. 4.37).

Not surprisingly, the size and inconvenience of these devices means patients generally dislike them. Care is required not to injure themselves, a particular problem in alcoholics and uncontrolled epileptics. Pin sites can become infected and may leave unsightly scars. After 6–8 weeks, loosening of the bone pins commonly occurs.

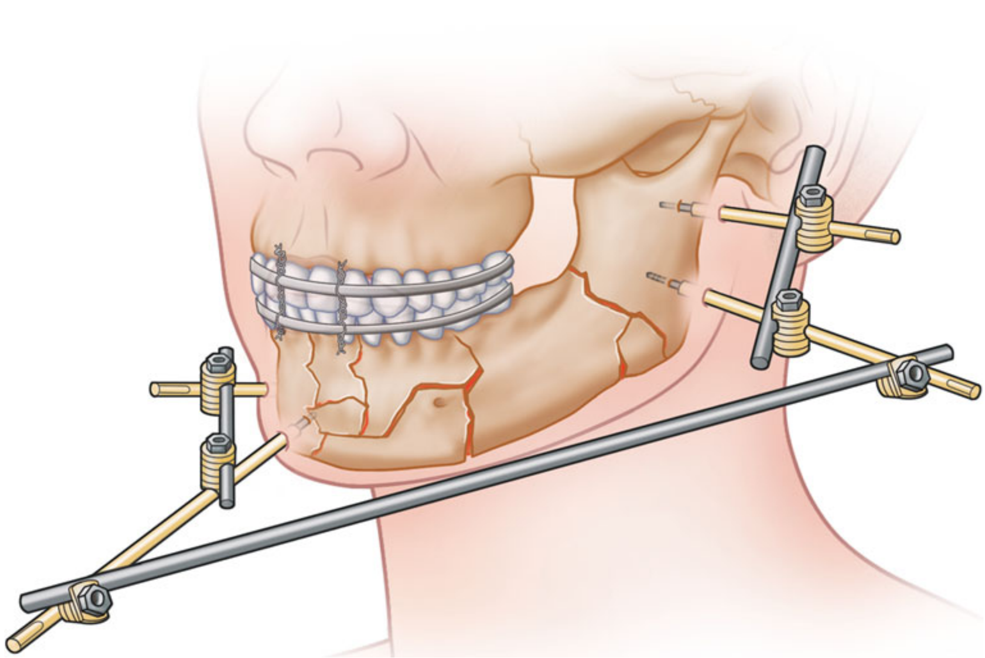

Fig. 4.35 Schematic view of external fixation

Fig. 4.36 Selection of external fixators (**a**–**c**)

Table 4.7 Principles of external fixation in midface trauma

Reestablish occlusion with IMF
Supporting pins must be placed in noninjured and good-quality bone (cranium/mandible)
Use minimum number of pins that will provide enough support
Pin position can vary so long as in sound bone
Avoid obscuring patients' vision with rods
Think in three dimensions: facial height, width, and projection. Not just the bite.

Fig. 4.37 (**a–d**) External fixation used in management of a gunshot injury

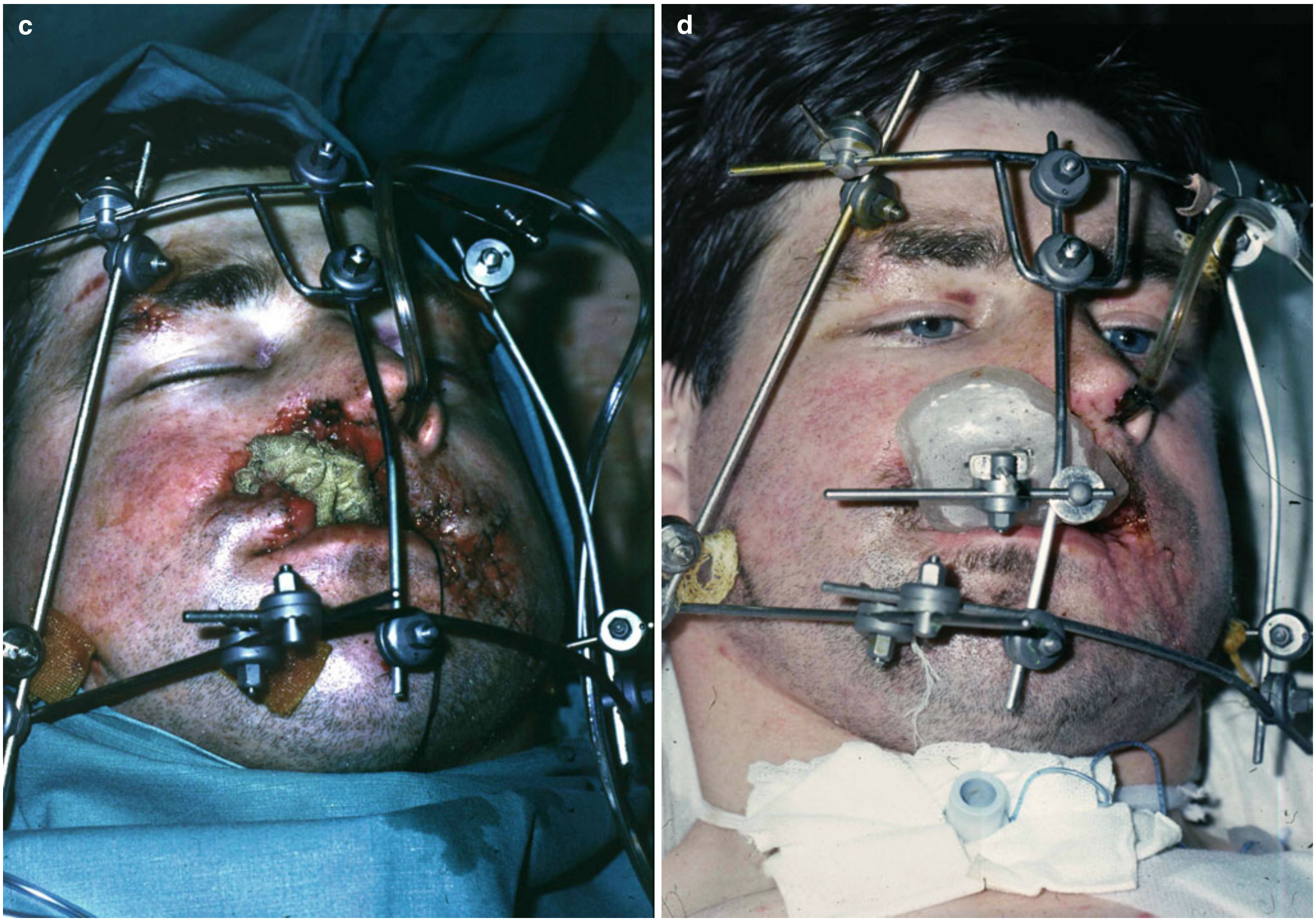

Fig. 4.37 (continued)

4.7.1 External Fixation of the Zygoma

This is an uncommon way of managing cheek fractures. In the example shown this was chosen because of its rapidity (the patient was critically ill), ease of application, and the presence of comminution at the buttress site.

Following review of the patient's computed tomography (CT) scans, two points of fixation are chosen. Only one pin either side of the fracture may possible (as in this case). The thickness of bone is determined (or estimated) so that the correct thread length on the pin can be used. Using a drill guide, a screw hole is drilled through a stab incision in the skin. The pin is then screwed into position. This procedure is repeated at the second site (and any subsequent additional sites). With all the pins in position the fracture is then gently manipulated into the reduced position. The pins are then fixed into their final position using universal joints and carbon rods as shown. The closer the rods are to the skin, the more rigid will be the fixation (*see* Figs. 4.38, 4.39, 4.40, 4.41, 4.42 and 4.43).

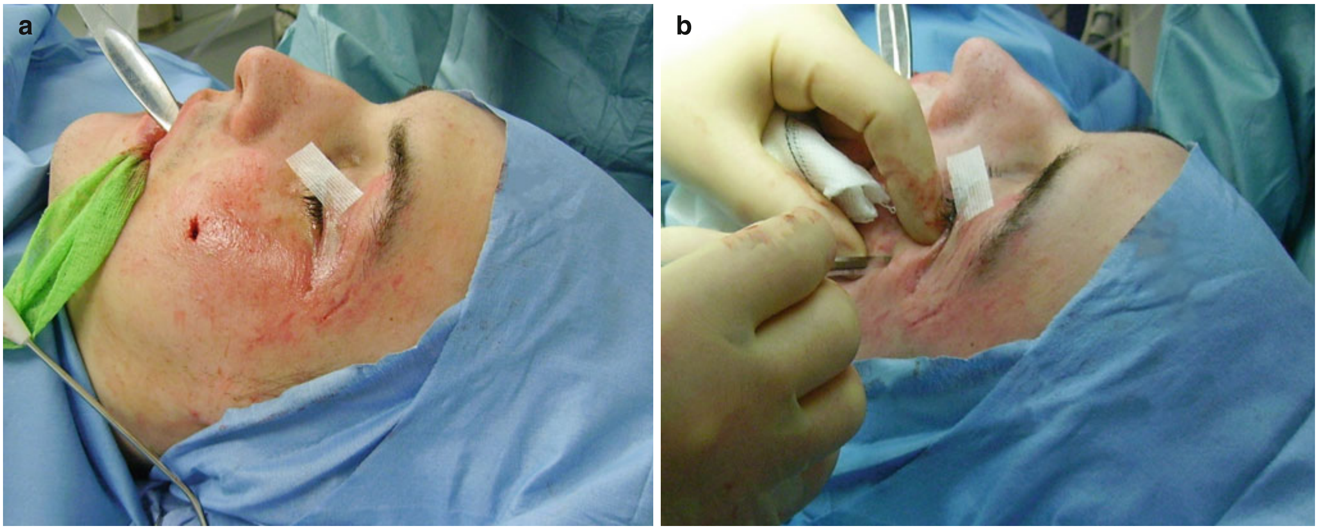

Fig. 4.38 Initial stab incision (**a**, **b**)

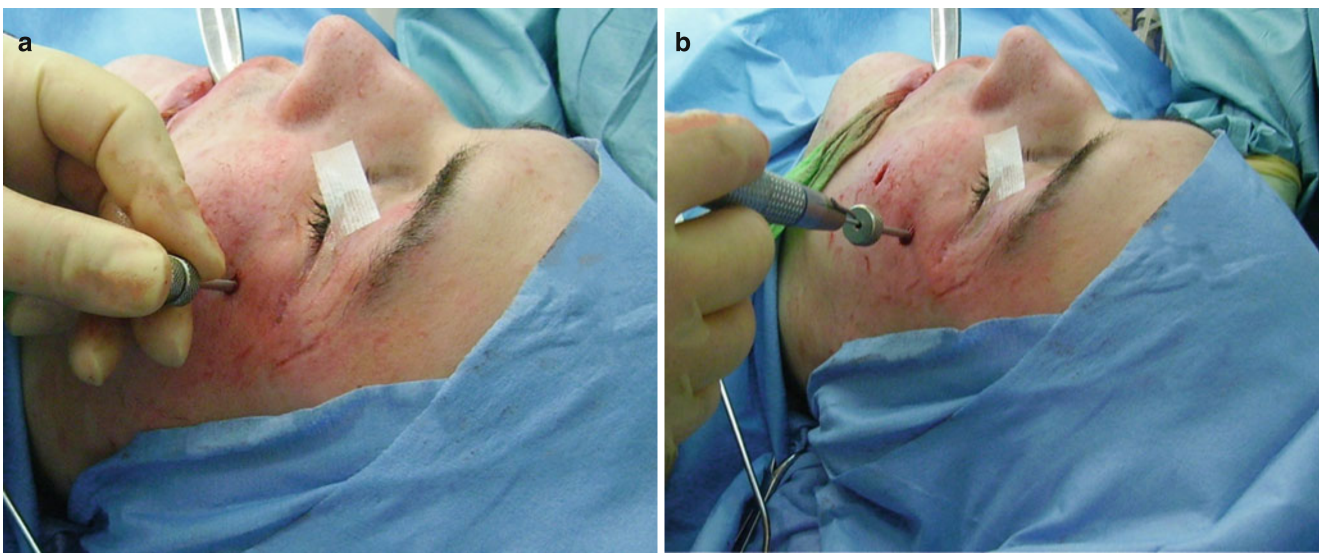

Fig. 4.39 Drill guide (**a**) and drilling over prominence of cheek (**b**)

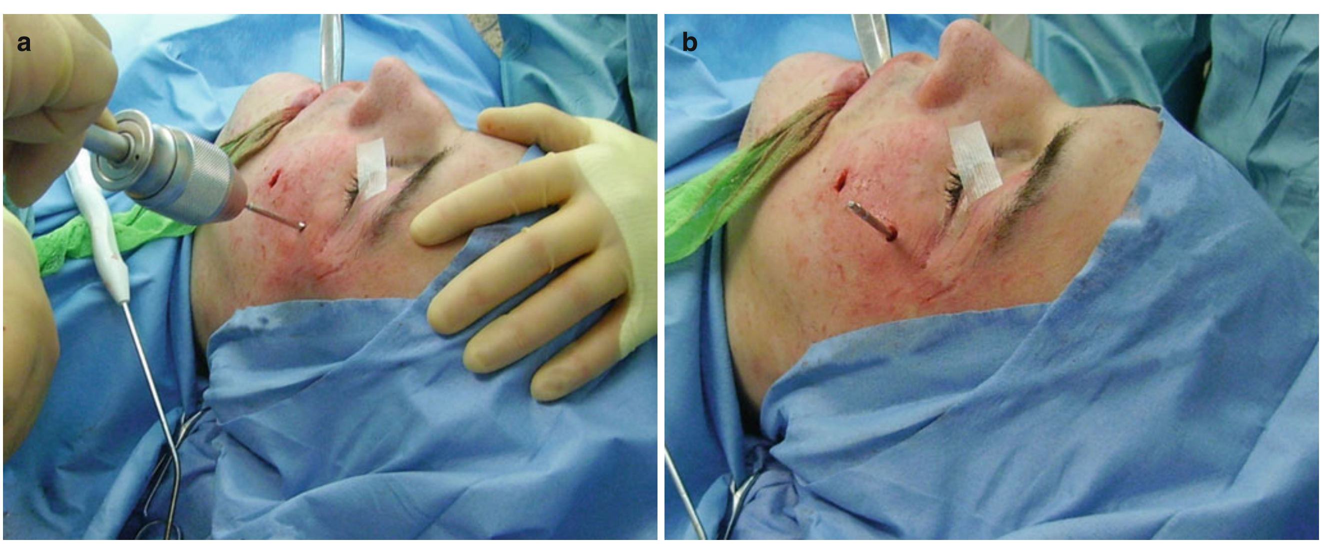

Fig. 4.40 Pin placement (**a**, **b**)

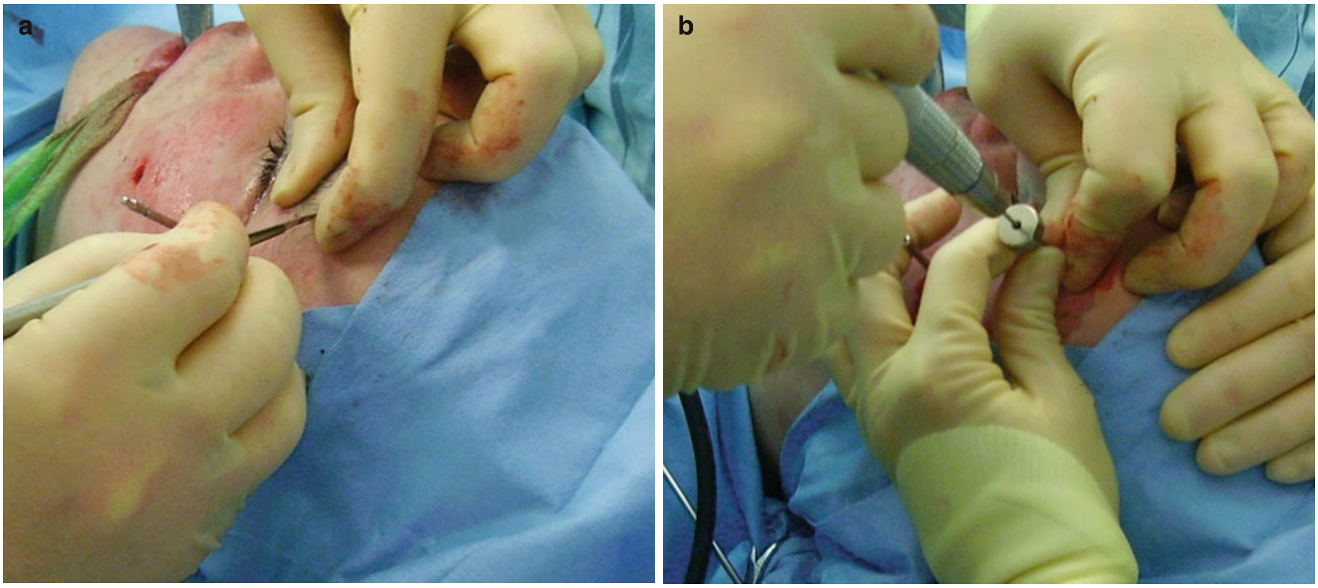

Fig. 4.41 Second stab incision and drill hole just above the fronto-zygomatic suture (**a**, **b**)

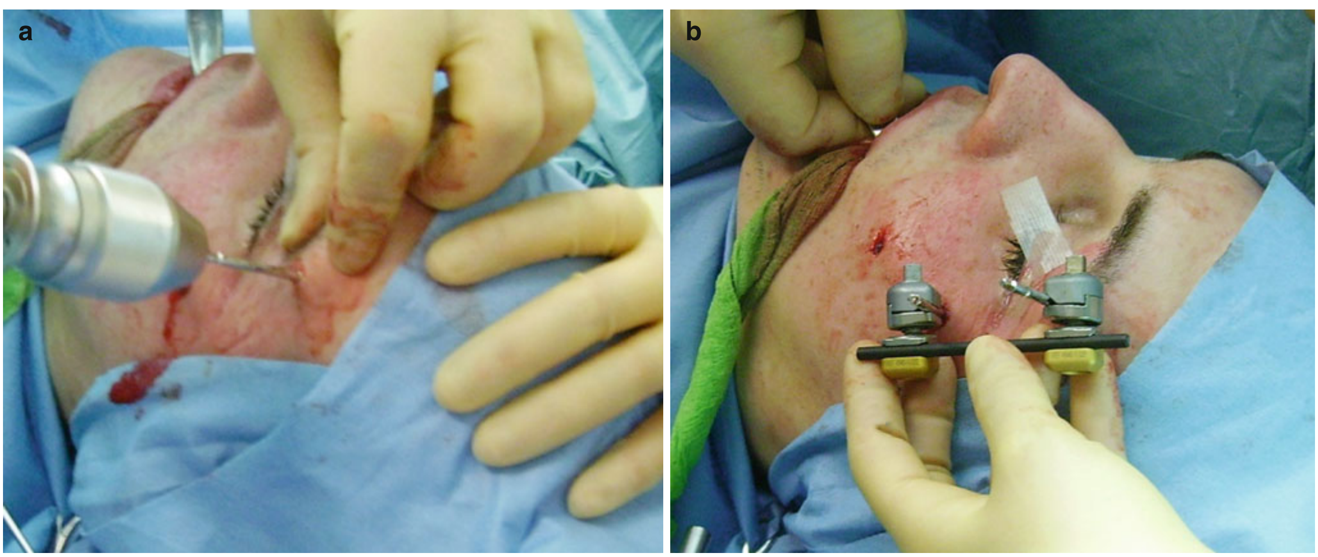

Fig. 4.42 Second pin and placement of rods (**a**, **b**)

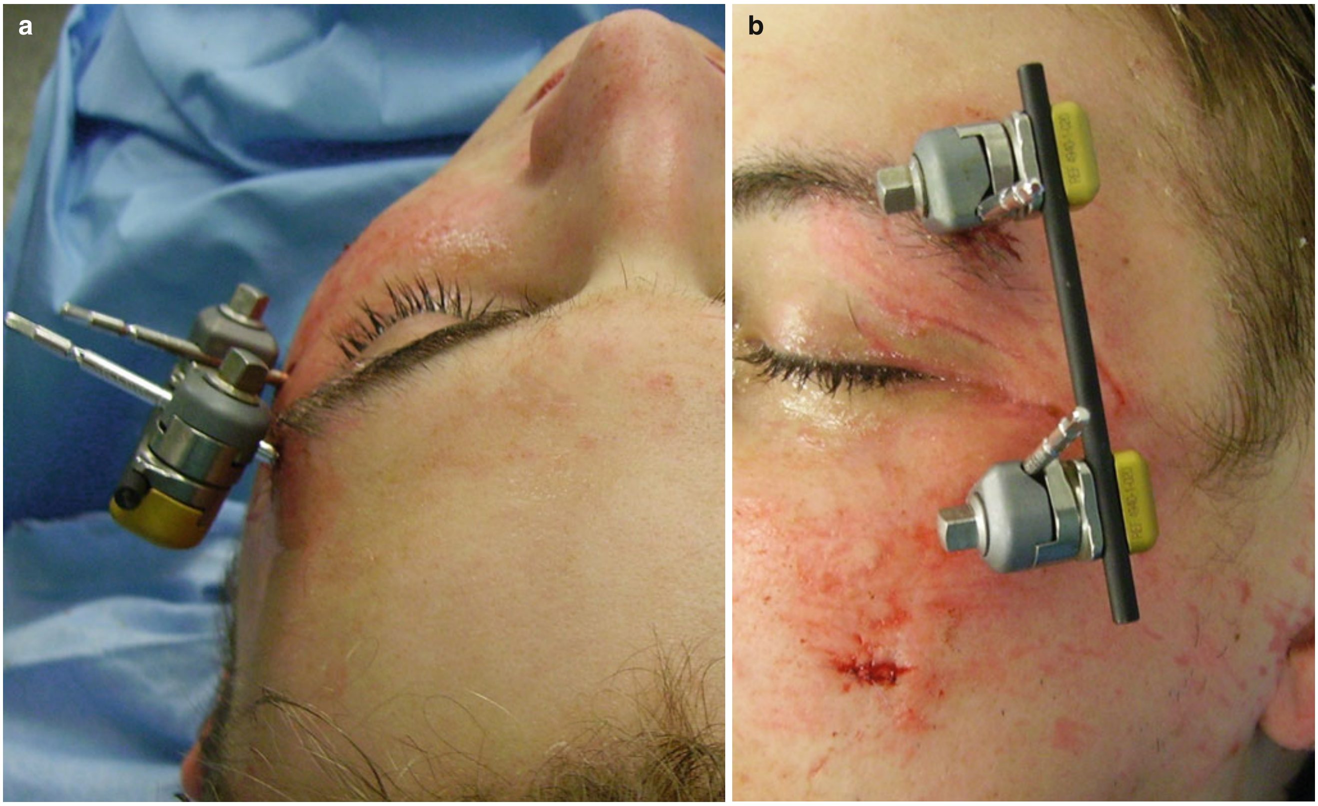

Fig. 4.43 Final configuration (**a**, **b**)

Case 1

4.7.2 External Fixation of the Mandible

This generally follows the same principles and steps as in fixation of the zygoma, although there are a few differences. In the zygoma, a single pin either side of the fracture may provide sufficient stabilisation. However, this is inadequate in the mandible due to the larger displacing forces. At least two pins either side of the fracture or defects are therefore required.

Placement of the pins is also slightly more complicated with the mandible. Bicortical screw fixation is required, which places the inferior dental (ID) nerve and dental roots at risk of injury. An intraoral incision is therefore needed to visualise the drill site. Due to the thicker overlying tissues, a longer drill guide with cheek retractors is also required. Nevertheless, the general sequence remains the same. Following review of imaging, the fracture is exposed and visualised intraorally. A stab incision is placed in the skin, through which a trocar is passed until it emerges through the periosteum and is seen through the intraoral incision (A curved clip can sometimes help in the blunt dissection down to bone). This is then replaced by the drill guide and the soft tissue retractors attached. The drill guide's position on the bone is visualised and the hole drilled. The drill (and inner sleeve of the guide, if used) is then removed and the pin screwed into place. This is repeated either side of the fracture. The fracture is then reduced and the pins fixed using universal joints and carbon rods (*see* Figs. 4.44–4.49).

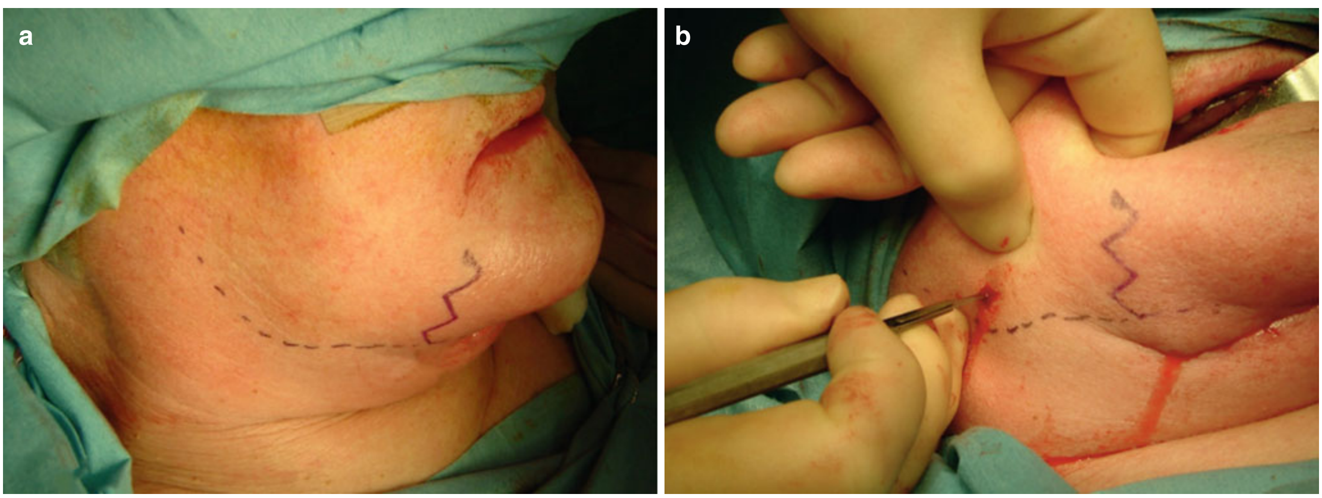

Fig. 4.44 (**a**) Fracture is marked. (**b**) Initial stab incision

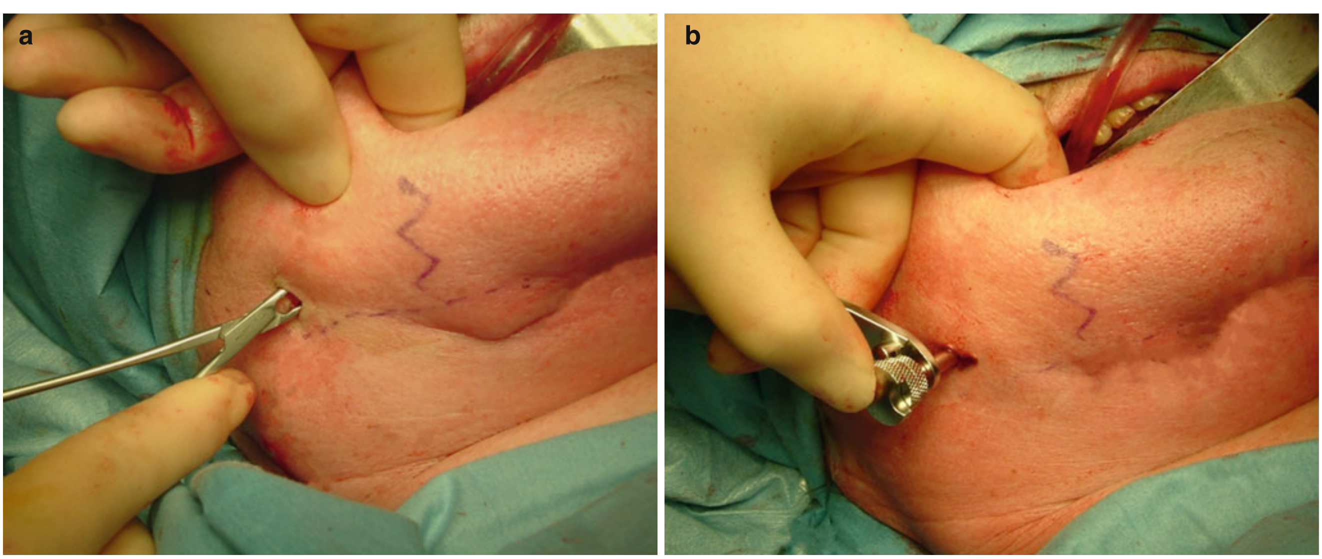

Fig. 4.45 Dissection through soft tissues (**a**) and placement of drill guide (**b**)

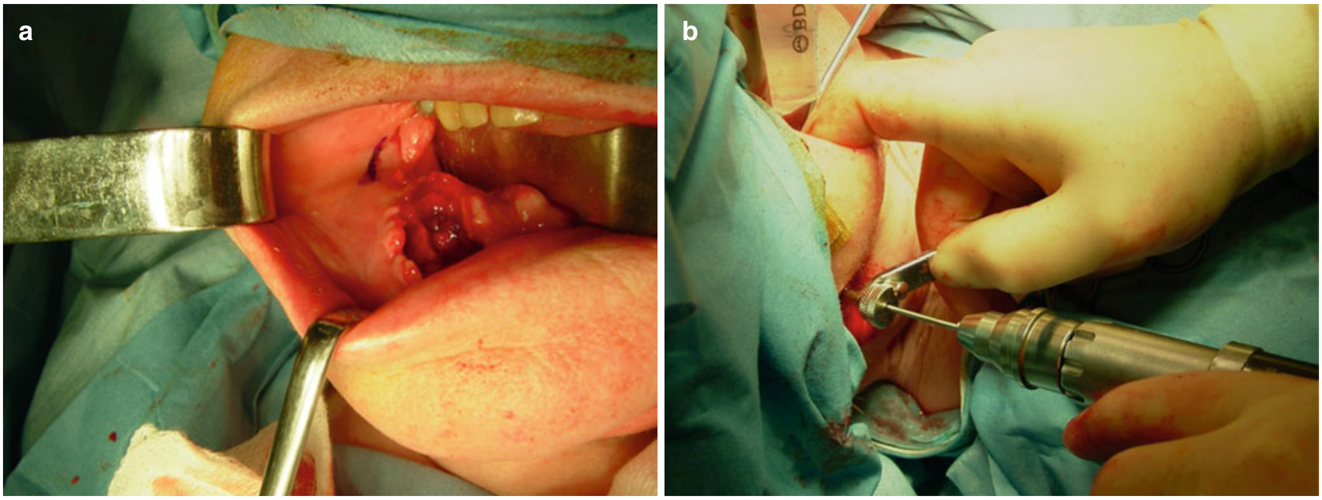

Fig. 4.46 Drill guide tip verified through intraoral incision (**a**). (**b**) Hole drilled

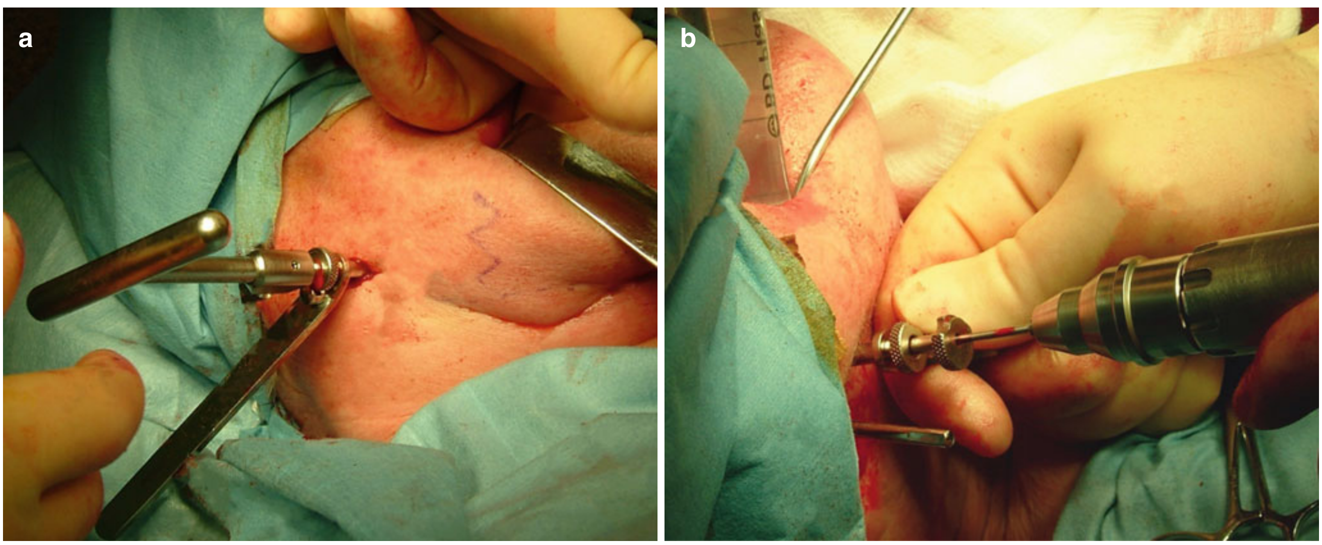

Fig. 4.47 Pin is screwed into place (**a**) and a second hole drilled (**b**)

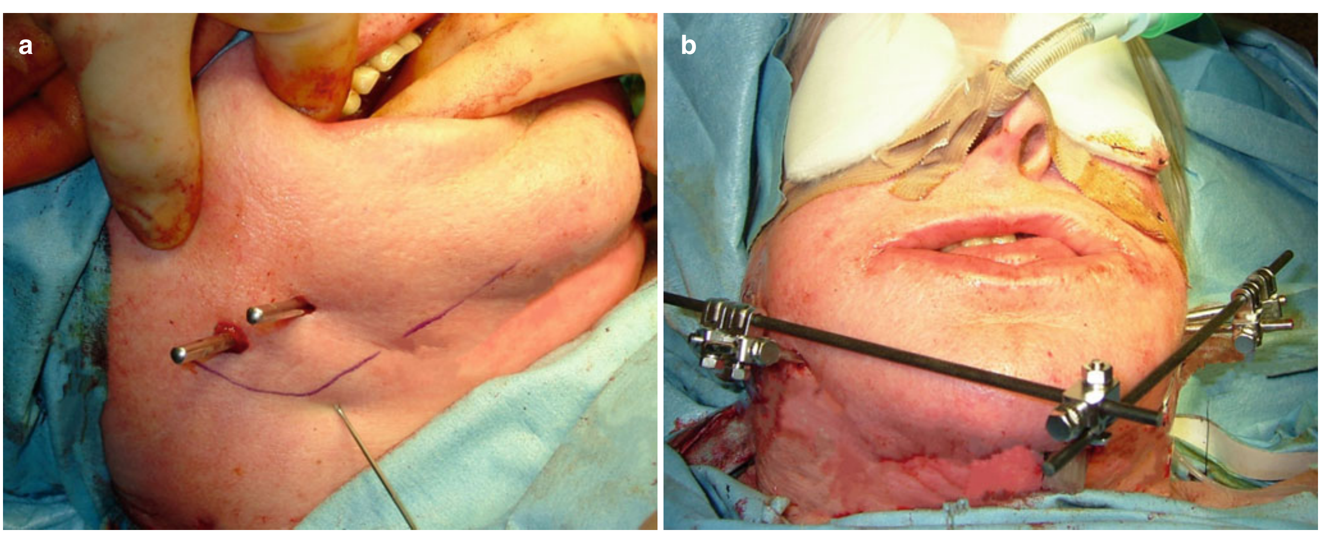

Fig. 4.48 Proximal pins *in situ* (**a**). Procedure is then repeated the other side of the fracture. Final set up is shown (**b**)

Case 2

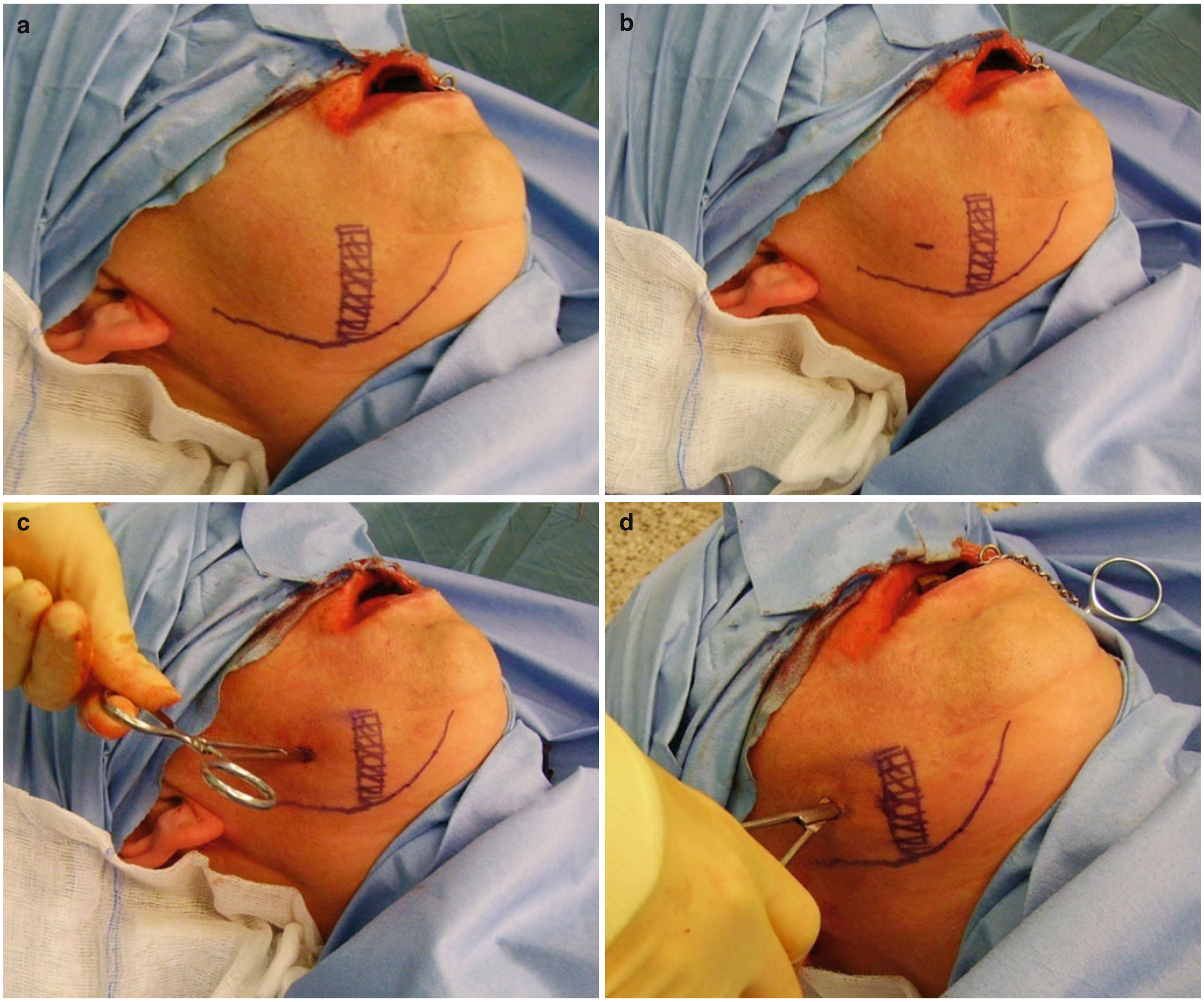

Fig. 4.49 (**a**–**i**) *See* Case 1 for sequencing

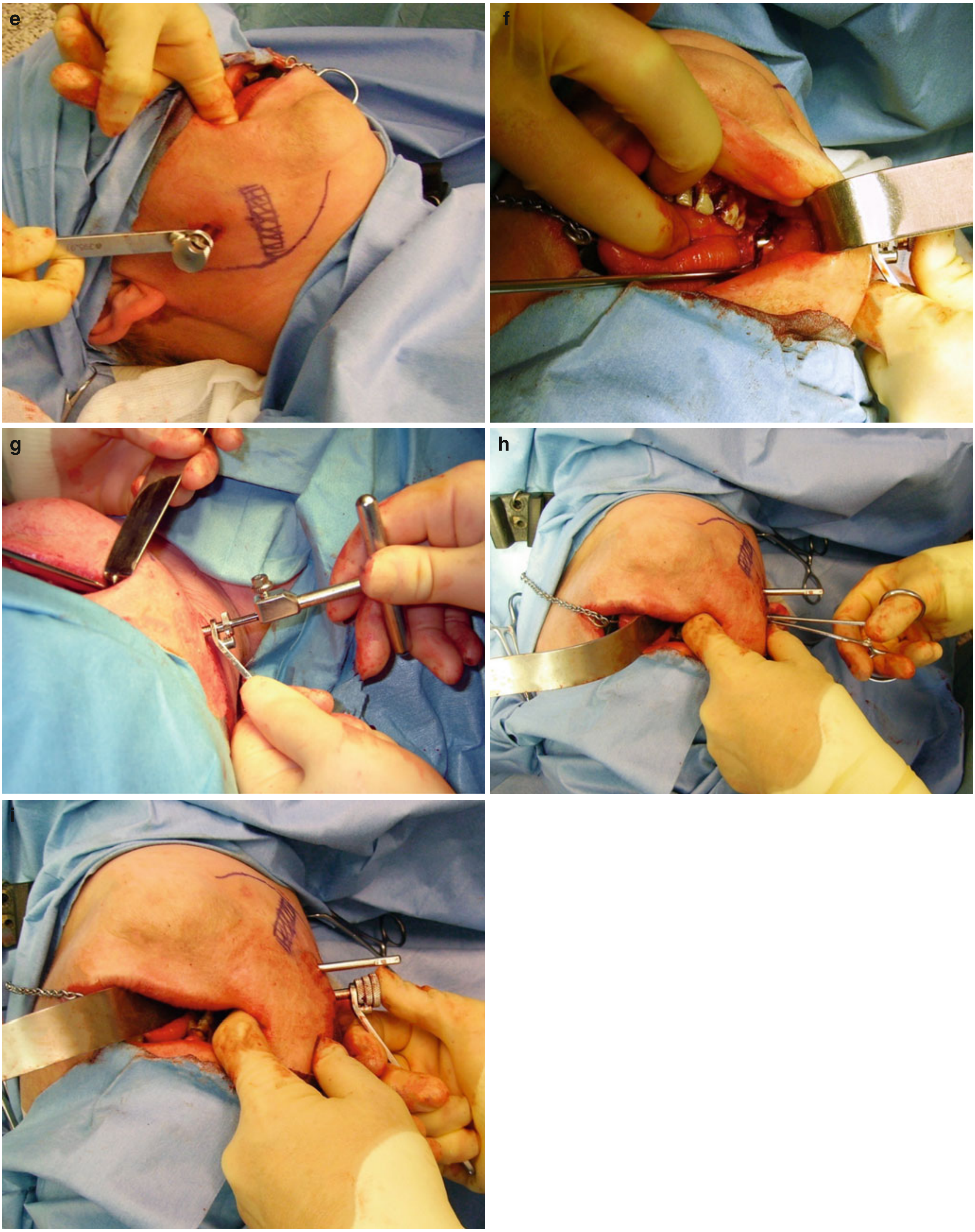

Fig. 4.49 (continued)

Specific “ex-fix” kits are available, but can be costly and may not be immediately to hand when needed. However, with a little creativity based on the understanding of these devices, several alternatives are possible.

1. Orthopaedic external fixators used in hand or wrist trauma are of comparable size and strength and will work just as well as a mandibular fixator.
2. Pins can be connected and held using an acrylic strip (sometimes referred to as a “biphasic fixator”). This is more of a historical technique but is very effective. (Remember that acrylic gets hot when setting, so care is required not to burn the patient) (*See* Figs. 4.50 and 4.51).
3. A variant of the biphasic technique is to initially support the pins by passing them though holes cut in a short segment of flexible tubing (such as a chest drain or endotracheal tube). Once the fracture has been reduced, the tube can be filled with acrylic and held until set (*see* Fig. 4.52).

Pin sites need to be cared for as with all external fixators. Patients need to be taught how to keep the pin sites clean and free from crusting. Infection is a potential complication if poorly looked after (*see* Fig. 4.52).

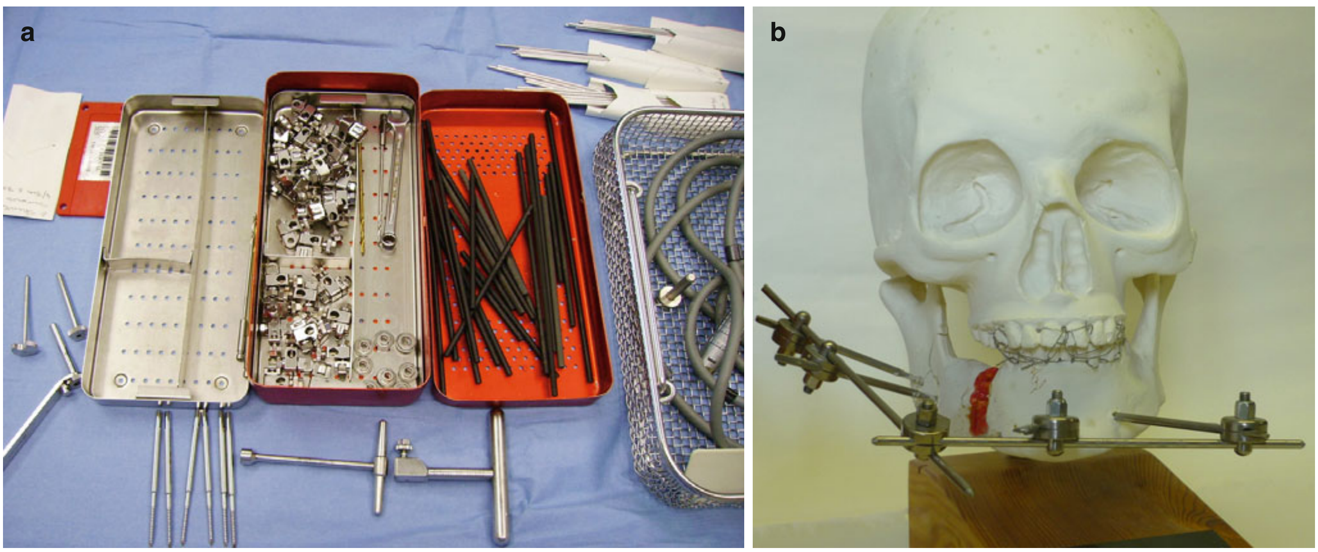

Fig. 4.50 (**a**, **b**) External fixator kits offer a lot of scope, but can be expensive

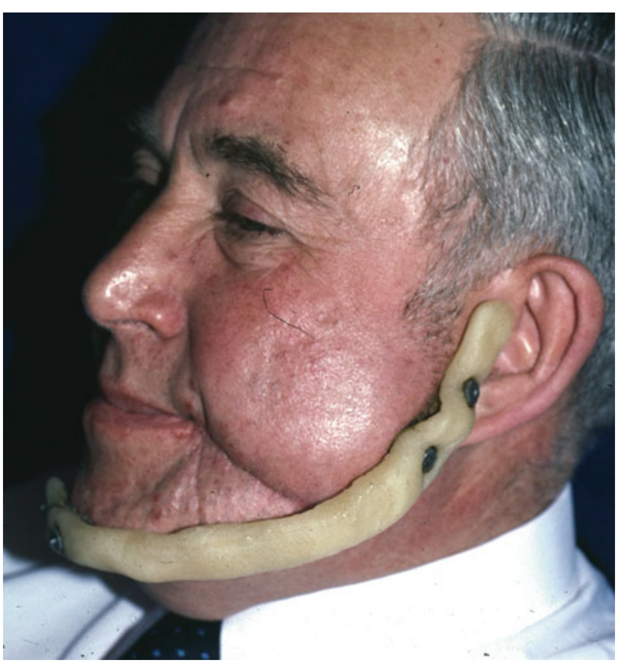

Fig. 4.51 Acrylic strip as an alternative to a more expensive kit

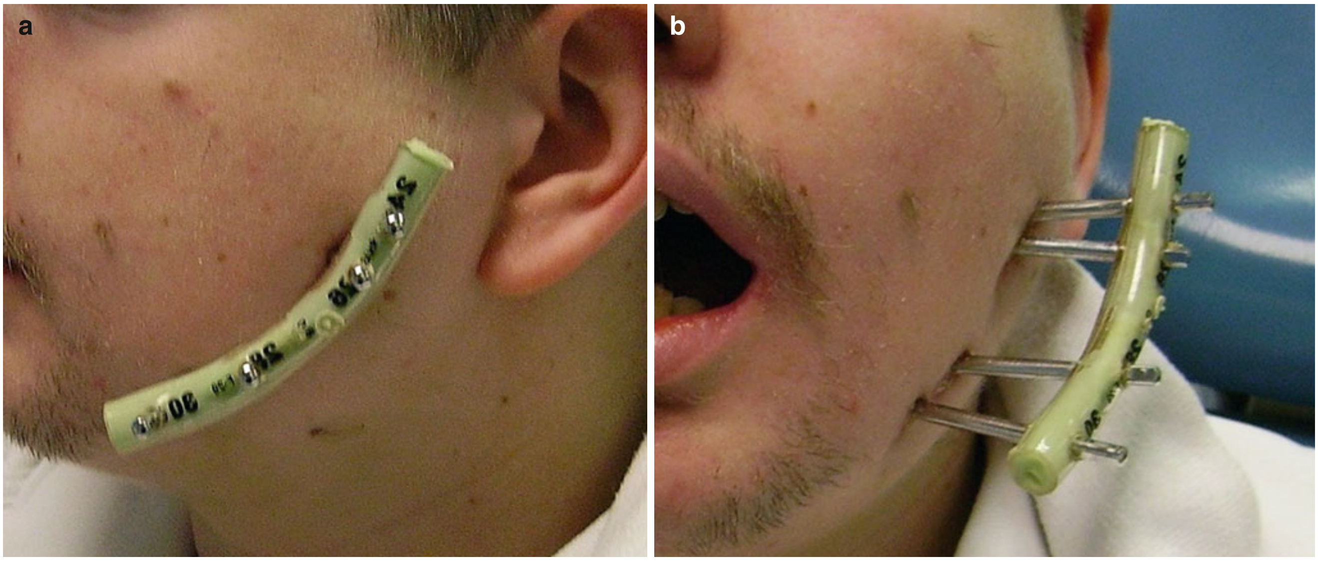

Fig. 4.52 Acrylic filled chest tube (**a**) or endotracheal tube (**b**) make good alternatives as well!

4.8 Biological Variation: Fractures in Children and the Elderly

Children and the elderly respond to treatments differently. Fractures in children heal much quicker than in adults. There is also much more scope for favorable remodelling as the child's face grows. In many ways therefore these are relatively easier fractures to treat and usually have minimal complications. In many cases internal fixation is not necessary, but if it is, microplating or resorbable systems are often used. Nevertheless follow-up during growth is necessary for some injuries, notably those around the canthal region, nose, and orbit. Ankylosis is also a particular concern following intracapsular fractures of the temporomandibular joint. Early and aggressive mobilization is desirable.

In the elderly, atrophic mandible the issue here is one of vascularity. The severely atrophic edentulous mandible is at risk of complications, especially those in which the radiographic height is 10 mm or less. This is for a number of reasons (*see* Table 4.8).

Opinions differ about the best way to manage these fractures, but generally there are two schools of thought. Each has its own set of advantages and disadvantages.

1. Heavy rigid fixation
2. Nonsurgical stabilisation

Much has been written about this in many excellent texts to which the reader is referred.

Table 4.8 Problems with the elderly atrophic mandible

Poor vascularity of bone, greater reliance on periosteum (avoid stripping)
Osteoporosis: difficulty supporting screws
Interfragmentary contact reduced
Greater reliance on plate strength rather than tension principle
Poor fracture healing
Poor general health/malnourishment
Risks with prolonged anaesthesia

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Injuries to Teeth and Supporting Structures

5

Michael Perry and Simon Holmes

Depending on local arrangements, injuries to the teeth and their supporting structures (dental and dentoalveolar injuries), may be managed by maxillofacial surgeons, dental schools, other specialists, or the patient's own dentist. Nevertheless, maxillofacial surgeons are often called on initially, to either provide advice or begin treatment. Whatever the local arrangements are, long-term follow-up is required (usually by the patient's dentist). This is because some complications can occur months or years later (see Fig. 5.1).

Fig. 5.1 Discolouration of a previously untreated upper left central incisor following trauma many months ago (**a**, **b**). Note the periapical lucency. The staining is from degraded products of the necrotic pulp. This is very difficult to treat

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5.1 Management

As newer dental materials become available, the comprehensive management of dental trauma will continue to evolve. What follows is therefore an overview, focusing on the early stages of care. If in doubt, follow local policies and procedures. Guidelines exist for many injuries.

5.1.1 Crown Fractures

Fractures of the crowns may involve the enamel only; enamel and dentine; or enamel, dentine, and pulp (see Fig. 5.2).

Injured teeth should therefore be radiographed (to look for subgingival fractures). They should also be tested for vitality.

- Fractures involving the enamel only generally do not require urgent attention. These teeth are usually slightly tender and may not have any obvious signs of injury. Cracks may be visible using a bright light to transilluminate the crown (a blue light is good for this). Teeth may also have minor irregularities of the edges. Treatment includes smoothing any sharp edges and relieving any occlusal pressure. Cracks can be sealed with an appropriate bonding agent or composite.
- When dentine is exposed, the tooth is typically tender to touch and exposure to the air. A small yellow patch of dentine may be visible. The exposure should be gently cleaned and an appropriate liner placed to seal off the dentinal tubules. The residual defect should then be sealed with a bonded composite material, or suitable alternative (see Fig. 5.3).
- When the pulp is exposed, it must be carefully managed. These teeth are very tender and the pulp is seen as a pink or red spot at the base of the defect. Fractures exposing the pulps of teeth usually require pulp capping, partial pulpectomy, or root canal treatment, depending on the extent of exposure (see Table 5.1 and Figs. 5.4 and 5.5).

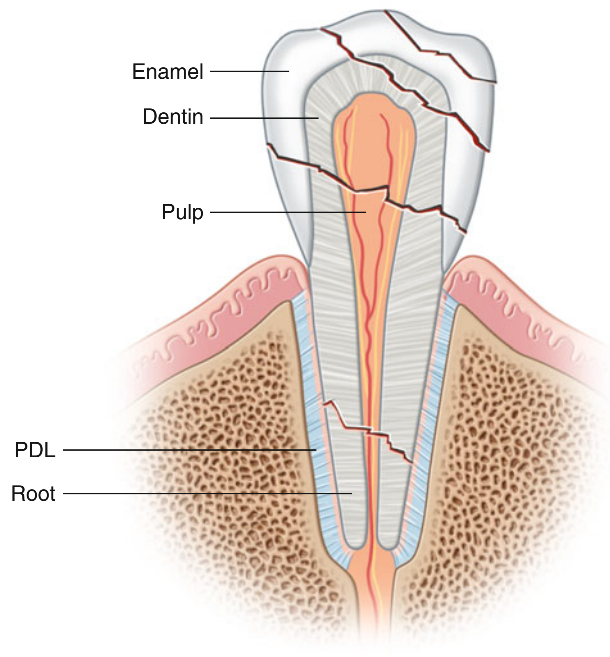

Fig. 5.2 Classification of fractures to the teeth

5.1.2 Fractures Involving the Crown and Root

Treatment of these fractures depends on the site of the fracture and the mobility of the crown. Successful long-term results depend on establishing a good seal at both the fracture and the pulp cavity. Fractures without displacement may still require root canal treatment to manage pulp necrosis and bacterial contamination. If the crown is loose, it will need support. If the crown is very mobile, it can be removed and examined to establish the extent of the fracture (*see* Fig. 5.8). Restoration may still be possible, but will involve advanced restorative techniques beyond the scope of this book (endodontics, post-retained crown, and sometimes gingivectomy/ostectomy).

5.1.3 Root Fractures

Mobile root fractures may require splinting for up to 12 weeks to enable union of the fracture. The tooth should be reviewed clinically and radiographically at around 3, 6, and 12 months. Vitality testing can be unreliable for up to 6 months. However, loss of vitality usually indicates that the pulp has become necrotic. In these cases, root treatment should be performed (see Fig. 5.9).

5.1.4 Traumatic Periodontitis

This is painful inflammation around the apex of a tooth that usually occurs following occlusal trauma. It can occur in vital, nonvital, and endodontically treated teeth. Radiographic examination may show very little, except for a slight widening of the periodontal ligament space. The tooth may be very sensitive to touch. Initial management involves establishing the vitality of the tooth and occlusal adjustment to relieve it from repeated trauma. Anti-inflammatory drugs should be prescribed. The tooth needs to be kept under long-term review and monitored for loss of vitality.

Fig. 5.3 Dentine exposure following fracture of the enamel

Table 5.1 Management of the pulp following exposure

Pulp capping: small recent exposures
Isolate the tooth with rubber dam
Thoroughly wash the exposure site with saline until the bleeding stops
Cover the exposure with calcium hydroxide
Restore the crown with a bonded composite or glass ionomer cement
Partial pulpectomy or pulpotomy: large exposures in immature teeth
Place local anaesthetic and isolate the tooth with rubber dam
Remove a small amount of the upper pulp and irrigate the remainder until the bleeding stops. Ferric sulphate applied topically for 10–15 s can help with haemostasis.
Cover the pulp stump with calcium hydroxide
Restore the crown
Review at 6–12 weeks and 6 monthly intervals thereafter to establish root formation
Root canal treatment
This is usually required in mature teeth with large exposures and immature teeth where there is radiographic evidence of root resorption following partial pulpectomy.

5.1.5 Luxated Teeth

Luxation, or displacement of a tooth, occurs when it is traumatically malpositioned in its socket. This requires a short period of splintage and occlusal adjustment if the tooth is very loose. If the pulp becomes nonvital or necrotic, root canal treatment should be performed. Long-term follow-up

Fig. 5.4 Pulp exposure is seen as a pink or red spot

is therefore required. Intrusion of a tooth with an incompletely developed root is managed by allowing the tooth to re-erupt. Intruded teeth with complete root development are repositioned and splinted if necessary. They may also require root canal therapy later (see Fig. 5.10).

5.1.6 The Avulsed Tooth

Avulsion (exarticulation) is the complete separation of the tooth from its socket. This is an urgent situation requiring

immediate action. If the tooth is put back almost immediately (i.e., within the first 5 min), there is a good chance it will take. However, if this is delayed more than 2 h, its prognosis for survival rapidly falls. The first priority is therefore to replant any avulsed adult tooth as soon as possible.

The likelihood of successful replantation depends on how long the tooth has been out of the mouth, its degree of contamination, and the condition of its periodontal tissues. It is the health of the periodontal tissues that is the key to success, not the pulp. If the periodontal fibers become dry, necrotic, or are removed (as a result of rough handling), the tooth may undergo resorption or can ankylose to the surrounding bone. Ultimately it may be lost.

Fig. 5.5 Traumatic loss of enamel and dentine with probable pulp exposure

Gentle handling is therefore crucial. Unfortunately, many lay people (and a few doctors) are worried about replanting a tooth back into its socket. If unable to replace the tooth, store it in an appropriate solution and refer to someone who can, as quickly as possible. The main reason why avulsed teeth do not reattach is that the periodontal tissues dry out. Therefore the tooth must be kept moist. In compliant patients, asking them to gently keep the tooth in their buccal sulcus (being careful not to chew on it) is one way to preserve it. Alternative storage media include milk, Hartmann's solution, and saline. Provided that the tooth is kept moist in milk it may be possible to replant it up to 24 h later. If the tooth has been dry for 20–60 min, some authorities recommend first soaking it in a balanced salt solution for 30 min. If it has been dry for more than 60 min it has been suggested to first soak it in citric acid for 5 min, then in 2 % stannous fluoride for 10 min, and finally in doxycycline for 5 min before reimplantation is attempted. This has been reported to reduce root resorption and increase the likelihood of successful take.

Other reported treatments include gently brushing the necrotic tissue from the root surface and soaking it in topical fluoride for 15 min. This process is reported to make the root more resistant to resorption. Some studies have shown that when a tooth has been out of the mouth for longer than 60 min, immediate reimplantation is no longer required. Root canal treatment of the tooth can therefore be performed on the tooth before it is put back.

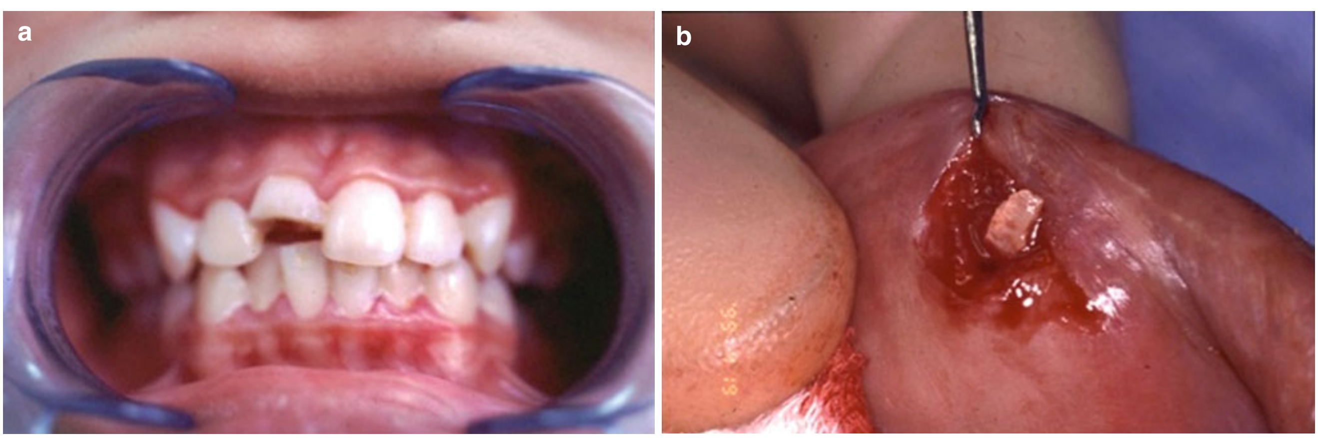

Fig. 5.6 Fracture of upper right central incisor (**a**). All fragments need to be accounted for. In this case the fragment was in the lower lip (**b**)

Missing fragments should always be accounted for, especially if there are associated lacerations (lips especially). Occasionally, if the fractured piece of crown is immediately retrieved, it may be bonded back to the tooth. This treatment alleviates discomfort, but the pulp may still require definitive care (see Figs. 5.6 and 5.7).

Fig. 5.7 Another example of "where's the tooth?" This was initially assumed to be lost at the time of injury, but declared itself shortly after, when the lip became infected (**a**–**d**)

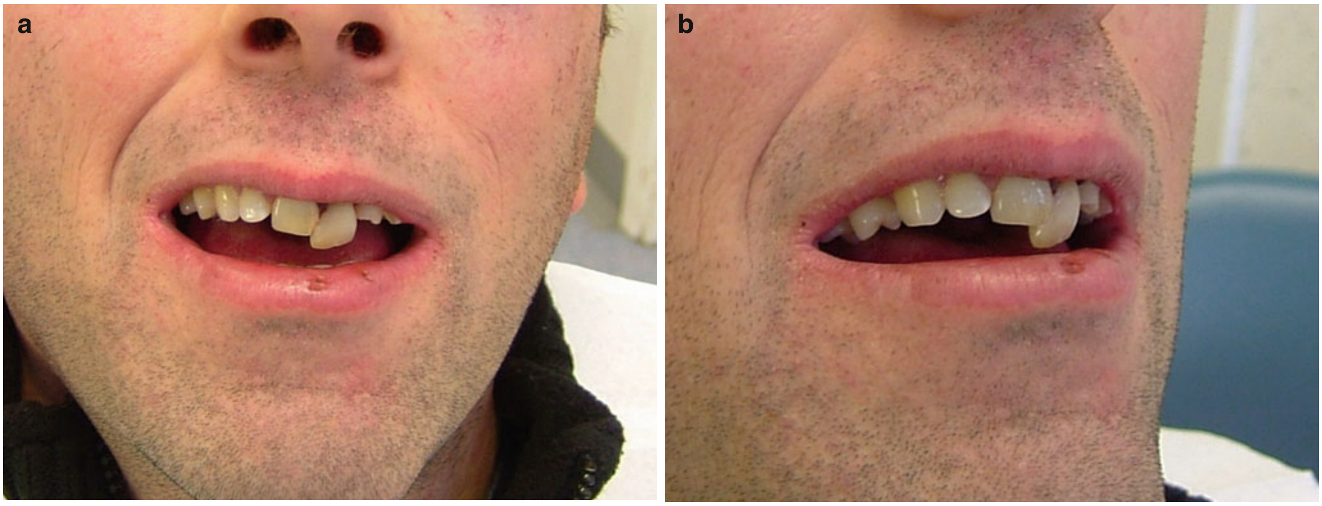

Fig. 5.8 Crown fracture extending into coronal third of the root (**a**, **b**). These fragments tend to be quite loose and need to be handled carefully

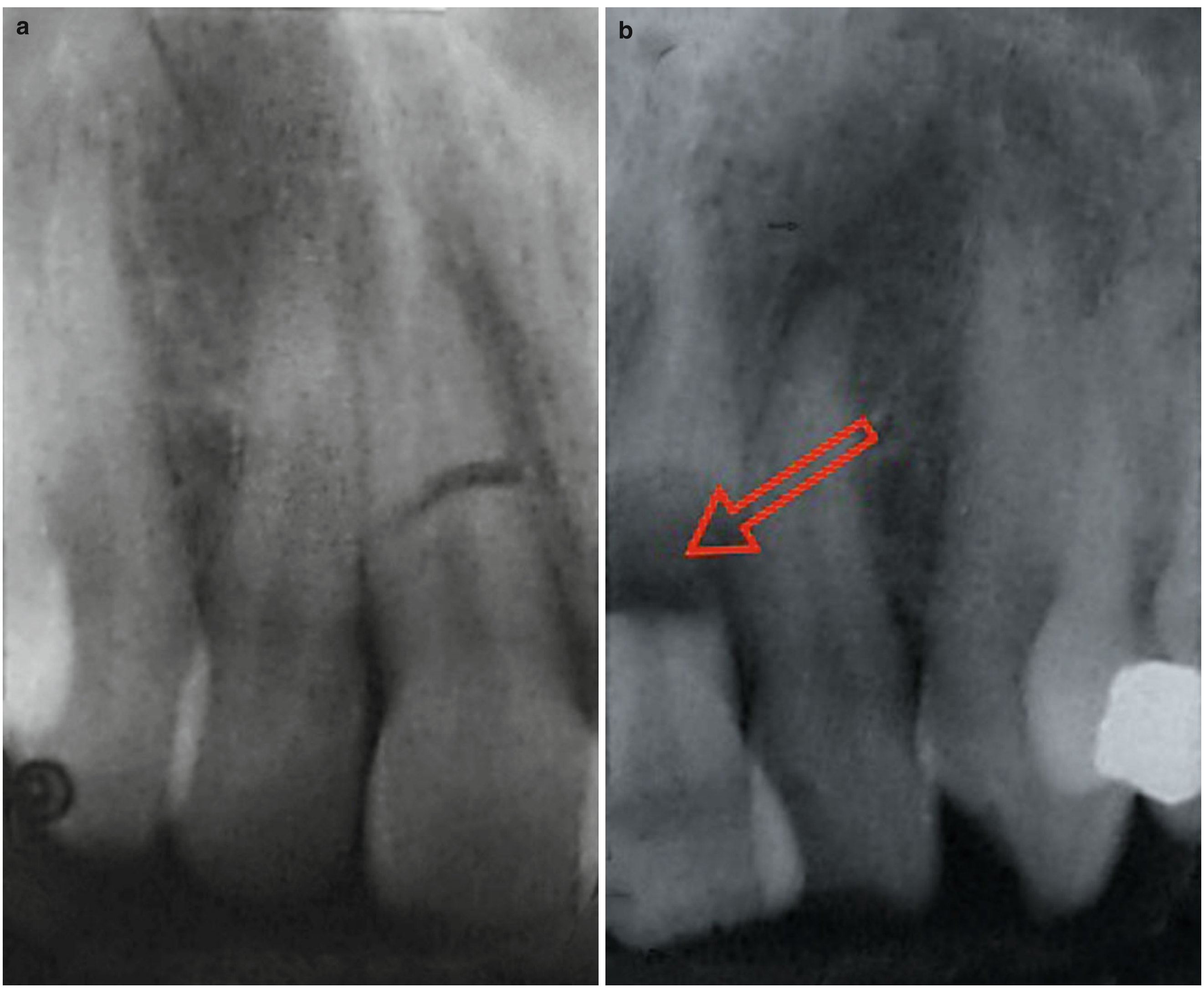

Fig. 5.9 Root fractures (*red arrow*) of the middle third of the root (**a**, **b**). These have a variable prognosis

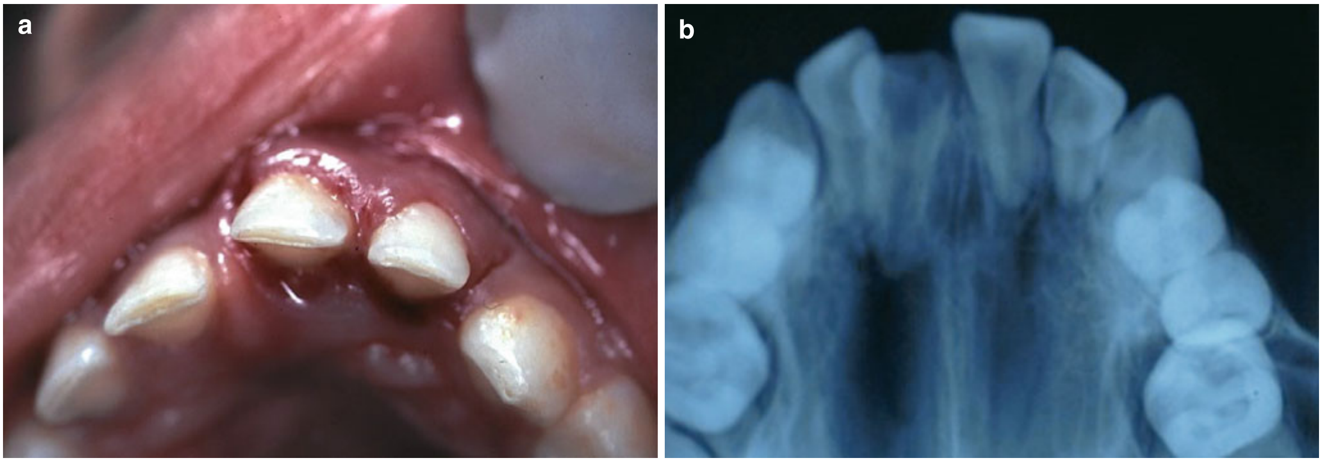

Fig. 5.10 Two examples of luxated teeth (**a**, **b**)

Fig. 5.11 (**a**, **b**) A very avulsed tooth (*red circles*), highlighting the need to consider all sites

Avulsed adult teeth should be replanted as soon as possible after the injury and splinted for 7–10 days. Root canal treatment should be considered after removal of the splint. This does not apply to deciduous teeth. Replanting a deciduous tooth may damage the underlying developing permanent tooth (see Fig. 5.11).

5.2 Splinting Teeth

Many types of splint are available for supporting displaced and fractured teeth (see Figs. 5.12, 5.13, 5.14 and 5.15 and Table 5.2).

Splintage does not need to be rigid. A splint that allows physiological movement of the tooth during healing is less likely to produce ankylosis. Fixation for a period of 7–10 days only is therefore recommended for avulsed teeth. The exception is when the avulsed or luxated teeth are associated with a dentoalveolar fracture. In these cases, splinting may be required for longer (4–8 weeks). During this time the patient should eat soft foods, avoid biting on the splinted teeth, and keep the mouth as clean as possible. In adults, the reimplanted tooth should have root canal treatment at around 1–4 weeks. In children (where the root has not completely

Fig. 5.12 Simple splinting of an avulsed upper left central incisor using wire and composite

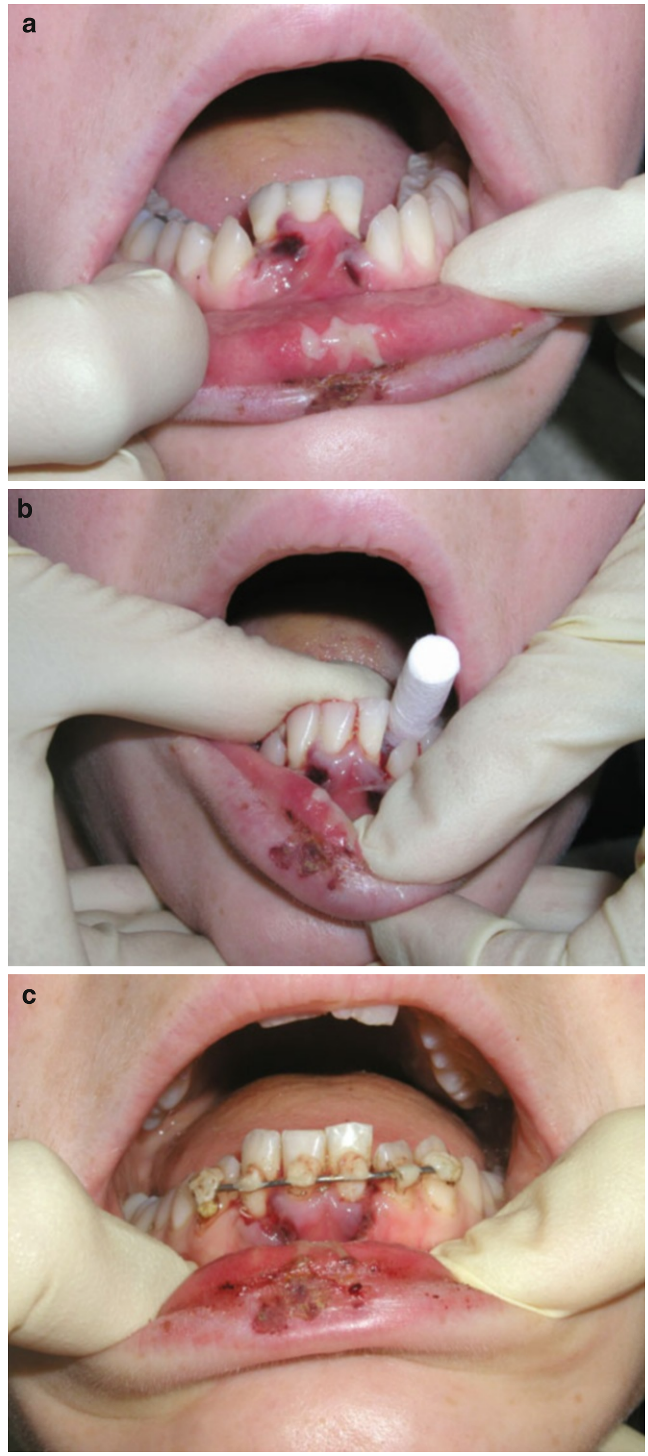

Fig. 5.13 Simple splinting of a dentoalveolar fracture with a similar technique (**a**–**c**)

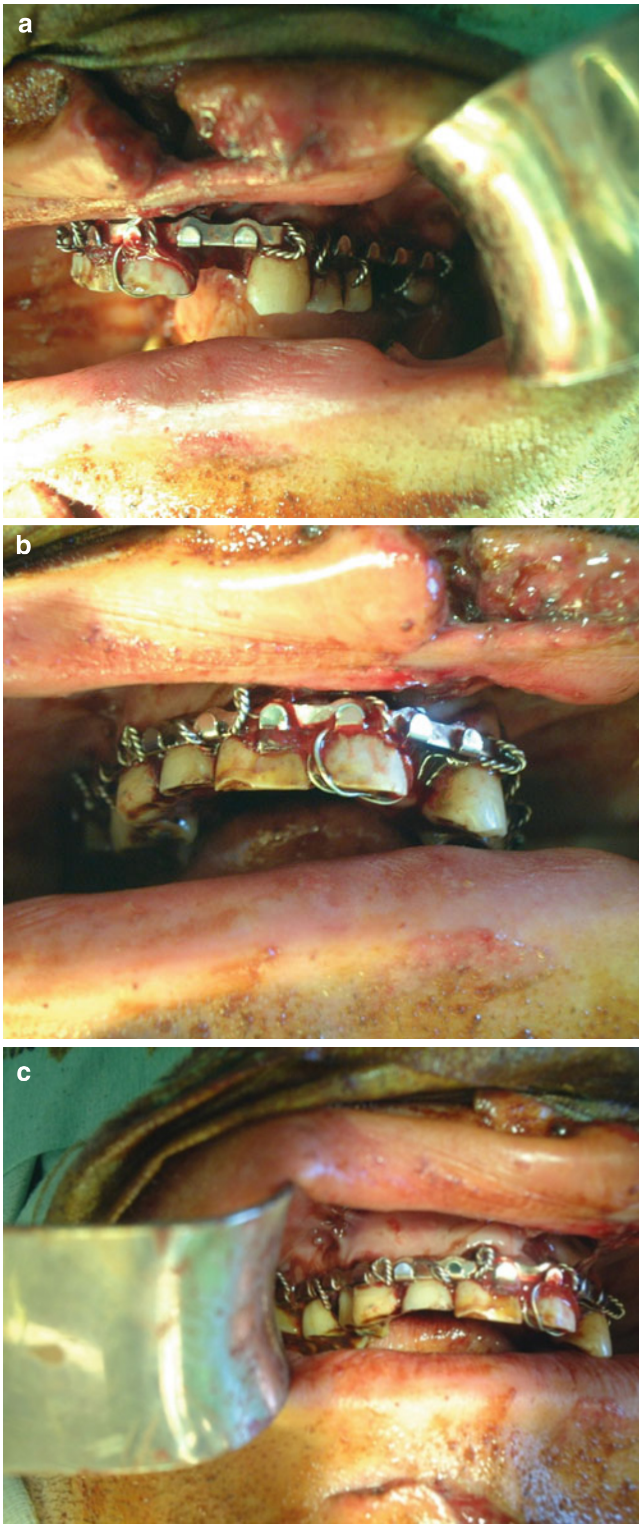

Fig. 5.14 Splinting using an arch bar and coronal tie wire to support the crown of an avulsed tooth (**a**–**c**)

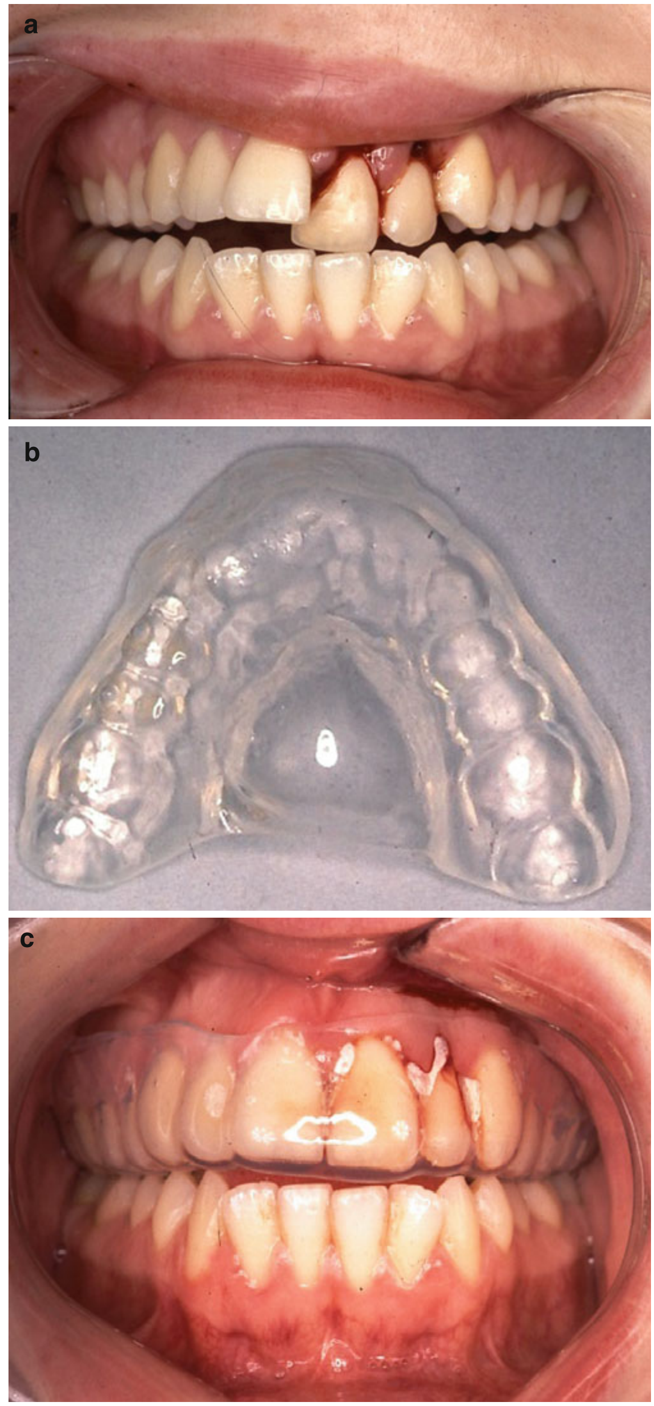

Fig. 5.15 Vacuum formed splints are quick and easy to make, plus have the benefits of being easy to remove and replace. But they do require impression taking at the time of initial care, which can be uncomfortable to the patient and can further loosen the tooth or teeth (**a**–**c**)

Table 5.2 Common methods of splinting teeth

The use of etched enamel retained composite
The use of polymethacrylate reinforced with wire or nylon
Vacuum-formed polyvinyl splints

Fig. 5.16 Remember the soft tissues. These need to be meticulously closed to cover any exposed bone or dental roots (**a**, **b**)

formed), this may not be necessary. The tooth needs long-term follow-up as the pulp may still die, resulting in pain, discoloration, or periodontal abscesses.

Consider antibiotics and tetanus prophylaxis in patients with accompanying significant soft tissue injuries. Any tears in the mucosa should also be repaired.

5.3 Dentoalveolar Fractures

Dentoalveolar fractures are fractures of the teeth and their supporting alveolar bone. The involved teeth may also have fractures of the crown or root, or they may be luxated or avulsed. Clinical signs include intraoral bleeding, tooth malposition or mobility, malocclusion and pain. These injuries should be regarded as open fractures. Consider also the possibility of an associated fracture to the supporting jaw. Management therefore includes antibiotics, tetanus prophylaxis (when necessary), and reduction and support of the fractures. Splinting the teeth is usually the method of choice, although very occasionally large dentoalveolar fractures may be internally fixed. If this is done, good soft tissue cover over the plates is essential (see Figs. 5.17, 5.18 and 5.19).

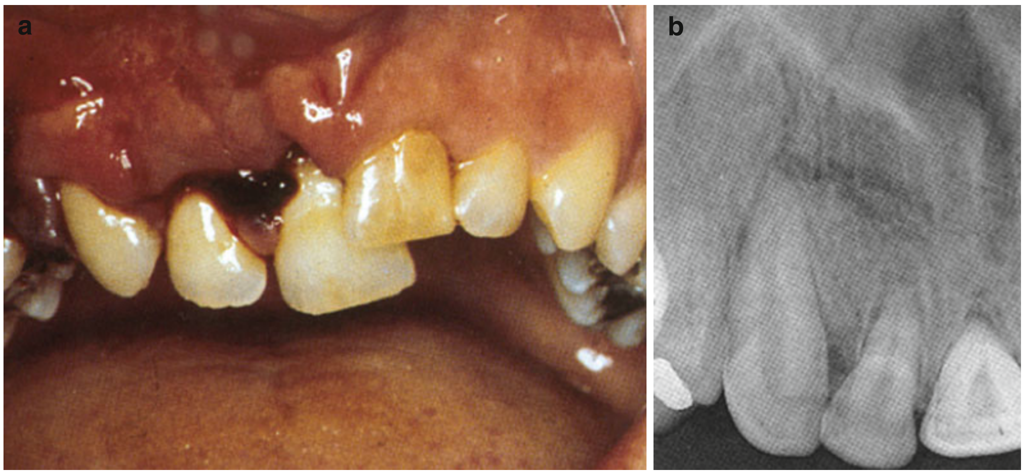

Fig. 5.17 Radiographs are required to identify dentoalveolar fractures (**a**, **b**). Otherwise these can be confused with luxation of the teeth

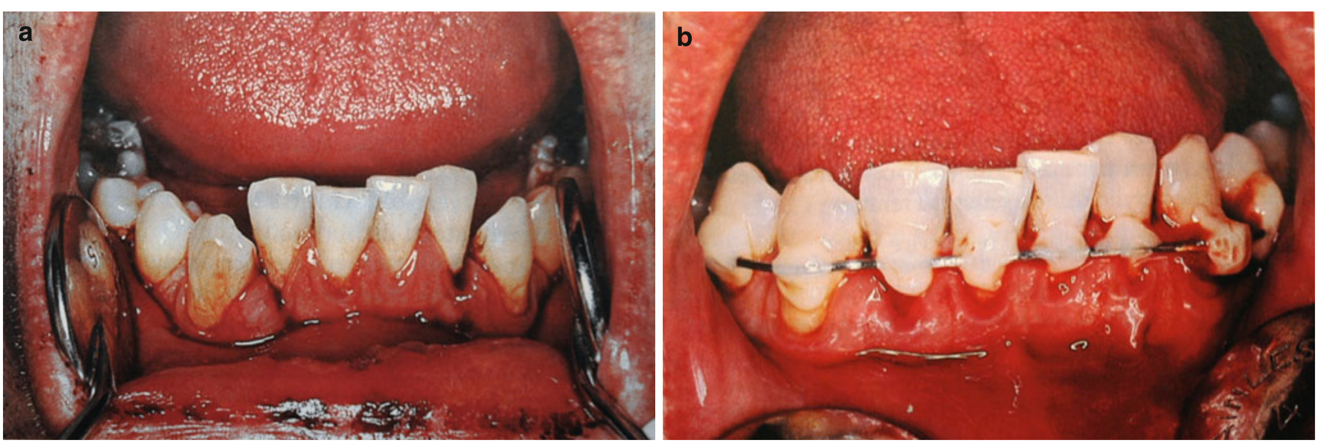

Fig. 5.18 Dentoalveolar fragment requiring long-term splintage (**a**, **b**)

Fig. 5.19 Complex dentoalveolar fractures with stripping of the gingiva and exposure of labial bone. Some gingival recession is likely in the long term (**a**–**c**)

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Mandibular Fractures

6

Michael Perry and Simon Holmes

Fractures of the mandible are common, and much has been published on how to manage them. However, debate still continues over which treatments give the best results in certain fracture types (notably fractures of the condyle, or fractures in severely atrophic jaws). Management of these fractures has evolved considerably during the past four decades, as our understanding in trauma (especially fracture biology, materials, and techniques) has improved. Consequently, patients are now much more likely to be restored back to their preinjury occlusion and function than was previously possible. Unfortunately, for a number of reasons, suboptimal outcomes still occur, although some of these complications (notably infection and malunion) are now much less likely.

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6.1 Applied Anatomy

The mandible forms the lower third of the facial skeleton and is responsible for the lower transverse facial width. It has a number of powerful muscles inserted along its length. These include the muscles of mastication (temporalis, masseter, medial, and lateral pterygoid), together with the suprahyoid muscles (digastric, geniohyoid, and mylohyoid). Collectively, these muscles enable the jaw to move. Some of them can generate considerable biting forces and these play an important role in generating the displacing forces that occur across a fracture. This has a major bearing on how some fractures are managed. The mandible also receives the insertion of genioglossus (which forms the bulk of the tongue). Loss of support for this muscle can place the airway at risk (see Fig. 6.1).

Morphologically, the mandible can be considered as a U-shaped long bone with articulating surfaces at each end (similar to the femur, radius, etc.). Anatomically it is divided into the following parts (see Fig. 6.2):

- Symphysis (in the midline)
- Parasymphysis (anterior to the premolar region)
- Body (premolar and molar region)
- Angle (third molar region)
- Ramus (from third molar to condyle)
- Condyle (neck and head)

The vertical ramus carries two processes: the condyle (which articulates with the glenoid fossa to form the temporomandibular joint [TMJ]) and the coronoid process (which receives the insertion of the temporalis muscle). The condylar head is supported on a relatively slender condylar neck—a frequent site for fracture. On the medial side of the ramus, the inferior alveolar (inferior dental [ID]) nerve and vessels enter the bone via the mandibular (lingual) foramen, passing forward through the "ID" canal. These provide sensory innervation and nutrition to the lower teeth. The mental nerve, an important terminal branch, exits the mandible through the mental foramen in the premolar region. This provides sensation to the lower lip (see Fig. 6.3).

The periosteum of the mandible is an important structure in determining the stability and displacement of a fracture. In young patients, this is a relatively strong and unyielding membrane. Significant displacement of fractures cannot occur if it remains intact. However, once the periosteum has been breached (by injury or surgical exposure), displacement and movement of the bones can occur under the influence of the attached muscles (and gravity)

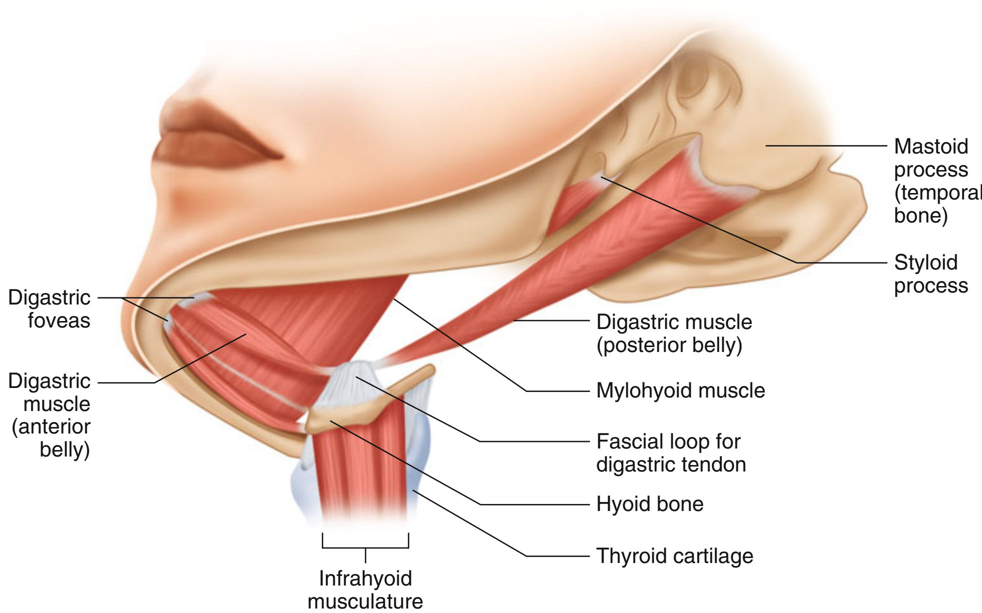

Fig. 6.1 The muscles of mastication and suprahyoid muscles play an important role in fracture displacement in the mandible

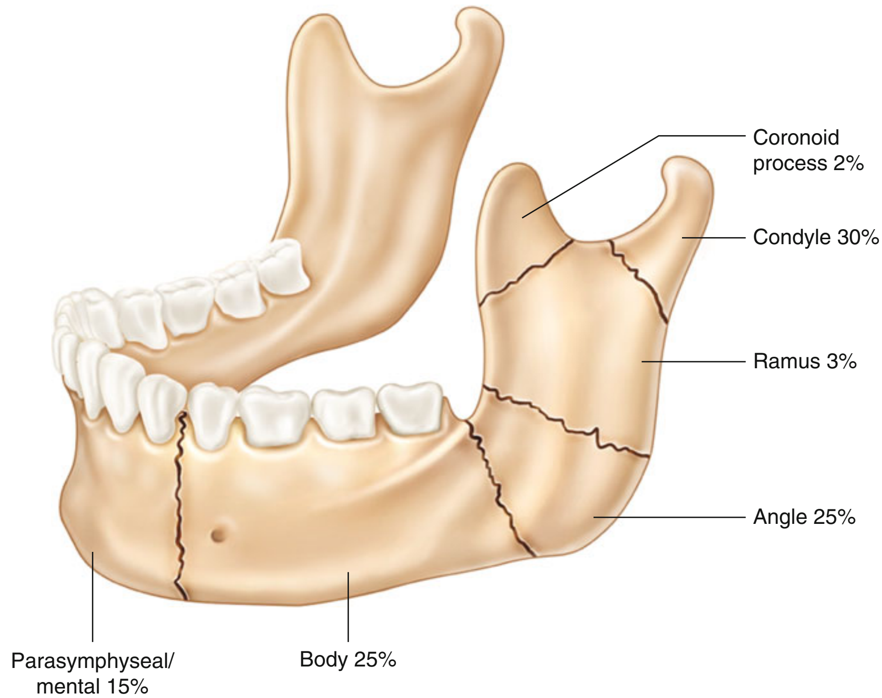

Fig. 6.2 Common fractures of the mandible

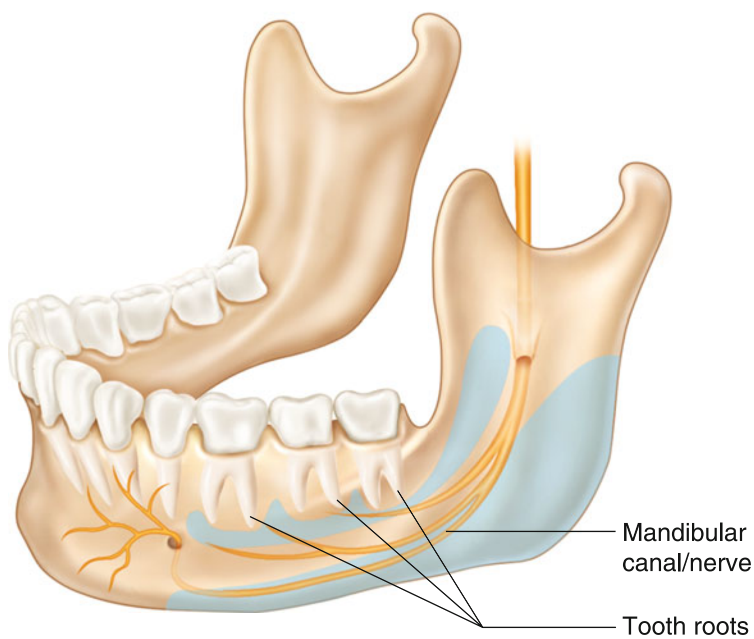

Fig. 6.3 The inferior alveolar (ID) nerve passes along the cancellous bone of the mandibular body. Displaced fractures along its path can result in traction injury

6.2 Clinical Examination

The importance of understanding the mechanism of injury has been discussed elsewhere, but it is of particular importance in the mandible. High-energy impacts that are sufficient enough to break the bone (particularly those resulting in comminuted or multiple-site fractures), not only put patients at risk from cervical spine injuries, but can also place the airway at risk from bleeding, swelling, and loss of tongue support. High-energy blows to the side of the jaw can also result in significant displacement of fractures involving the ID canal. This in turn may result in traction injuries (or even avulsion) to the nerve itself, adversely affecting its likelihood of recovery. The classic "guardsman's" fracture (a midline/parasymphyseal fracture, associated with bilateral fractures of the condyles), typically occurs following a faint or fall onto the chin. This is an example where both condyles and the cervical spine (especially in the elderly) need to be carefully assessed based on the mechanism of injury.

Symptoms and signs of a fractured mandible are shown in Table 6.1.

The hallmark of a mandibular fracture is a change in the patient's occlusion. This is an important sign that can be easily overlooked or misinterpreted in patients who have preexisting abnormal bites. Hence it is a *change* in the bite following injury that is the key to diagnosis. However, the presence of a normal occlusion does *not* rule out a mandible fracture. Furthermore, not all altered bites are caused by mandibular fractures (see Table 6.2).

Numbness of the lower lip is a useful sign. This may signify stretching of the inferior alveolar nerve as a result of fracture displacement. However, numbness can also occur in the absence of a fracture. Documentation of numbness before treatment is particularly important, as any persistence is often a source of patient dissatisfaction and litigation.

Sublingual haematoma is highly suggestive of a fracture involving the lingual plate of the mandible. The airway should be reviewed regularly in patients taking antiplatelet agents or anticoagulants (notably aspirin and warfarin), as continued bleeding can place it at risk of increasing obstruction (see Fig. 6.5).

Table 6.1 Symptoms and signs of mandibular fracture(s)

Jaw pain, especially on talking and swallowing
Drooling, swelling
Altered bite
Numbness of the lower lip
Trismus and difficulty in moving the jaw
Loosened teeth/mobility of fractured segment
Gingival bleeding/sublingual haematoma
Medial displacement of the condyle can compress the trigeminal nerve (rare)
Facial weakness following direct blows to the side of the mandible has also been reported

Table 6.2 Change in patient's bite following injury (*see* Fig. 6.4)

Consider the following:
Mandibular fracture
Maxillary fracture
Dentoalveolar fracture
TMJ effusion or haematoma
Fractures zygoma: occasionally a displaced fracture can "flex" the ipsilateral maxilla, resulting in premature occlusal contact with the mandible.

Fig. 6.4 Anterior open bite. This can have several causes following trauma. It does not necessarily indicate a fracture of the mandible

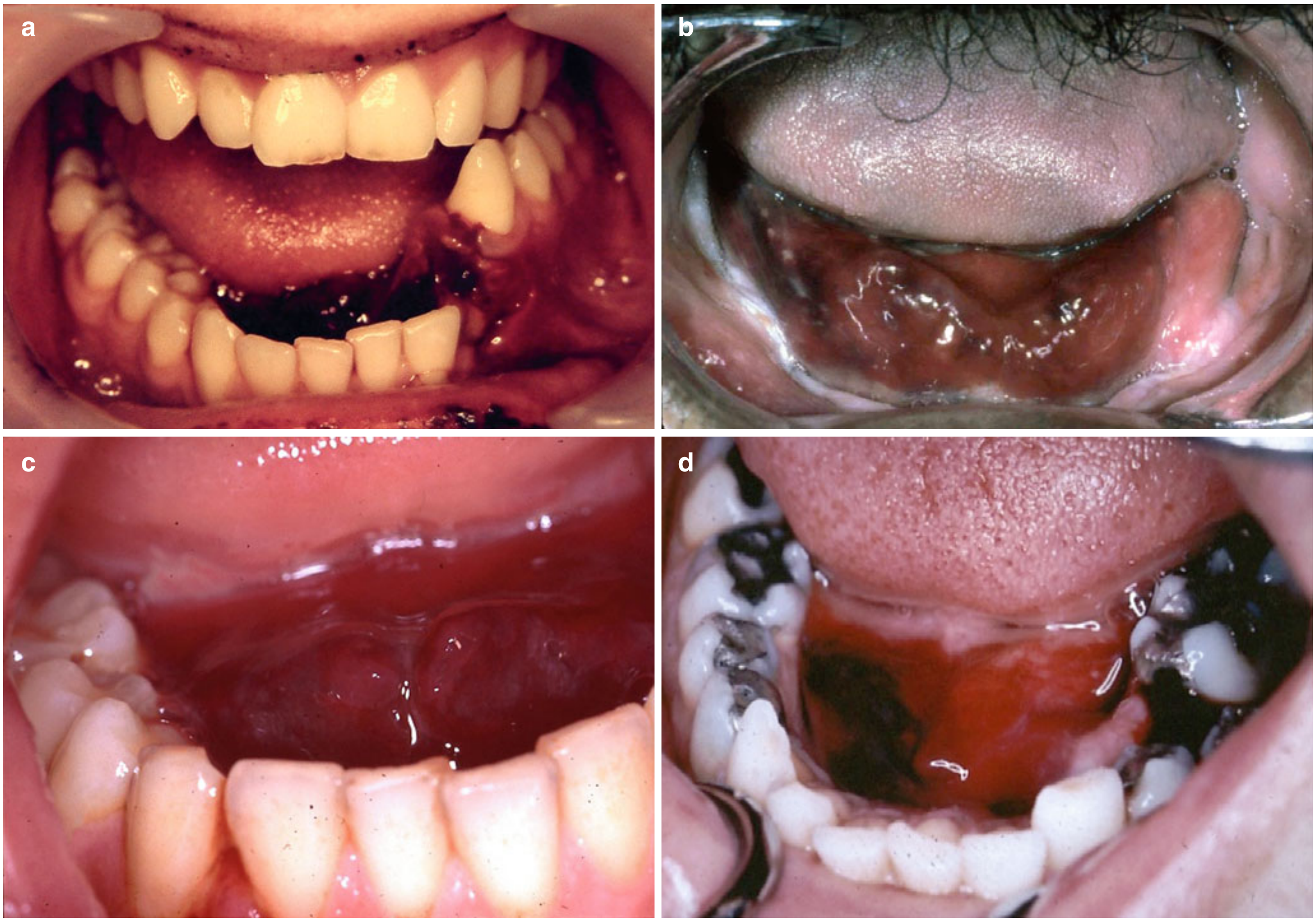

Fig. 6.5 Sublingual haematoma (**a**–**d**). This is usually a reliable sign of a fractured mandible

6.3 Imaging

> Approximately half of patients with a mandibular fracture will have multiple fractures present. In about 10 %, three or more sites will be involved. Therefore, if you see one fracture, look for another (e.g., pelvic fractures).

Radiographic studies (usually plain films) are not required in every patient to rule out a fracture of the mandible, provided a thorough clinical examination has confidently excluded signs of one. In an alert and cooperative patient, if a fracture is thought *not* to be present, "springing" the mandible by gently compressing the angles (similar to "springing" the pelvis), should be possible without causing pain. Similarly, asking the patient to open their mouth, with increasing force against resistance at the symphysis, should also be pain free. A clinically intact jaw should be able to resist both these deformational forces without discomfort and therefore avoid unnecessary imaging. However, when a fracture or fractures are evident or suspected, imaging is then required. Plain films are usually the first choice, although with high-energy injuries it may be simpler to move directly to computed tomography (CT).

A commonly taught principle in trauma radiology is to obtain at least two films, each taken at right angles to the other. With the mandible this is often thought to be achieved by taking an orthopantomogram (OPT or OPG) and a posteroanterior (PA) view. However, the views of the symphyseal region in both these films are in reality quite similar and certainly not at 90°. The cervical spine is also superimposed and can obscure detailed assessment. If uncertainty exists in this region, a lower occlusal view is a useful additional measure. This is particularly useful in visualising the lingual plate and the presence of any avulsion fractures in the genial region. The genioglossus and geniohyoid are both attached to the genial tubercles and any loss of support here may put the airway at risk.

Panoramic views require a cooperative patient who can stand, a requirement that may not be possible if the patient is intoxicated or has multiple injuries. If this is not possible, oblique views can often be obtained (see Fig. 6.6). Alternatively, plain films may be withheld until the patient is in a better condition. Although not ideal, this may be appropriate in those patients in whom immediate intervention is not necessary (i.e., those with a patent airway, no major bleeding and a relatively intact jaw).

Computed tomography (CT) imaging may be required following high-energy injuries or in those patients unable to undergo routine radiography (due to the presence of torso, cervical spine, or brain injuries). With the newer high-speed machines, the extra time required to image the face is now considerably reduced, and the previous

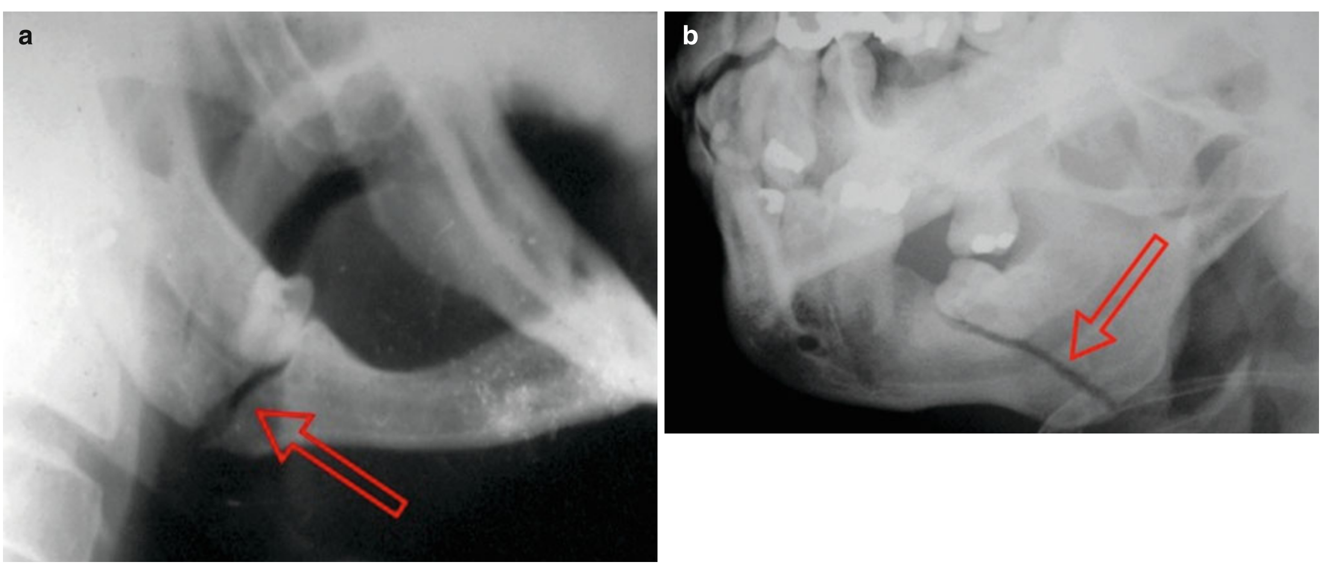

Fig. 6.6 (**a**, **b**) Lateral oblique views showing fractures of the mandibular angles (*arrows*)

arguments suggesting that facial CT "wastes valuable time" in sick patients should no longer apply. More recently, the use of cone-beam CT (CBCT) in dentistry has been reported as an accurate and reliable alternative to conventional CT, providing good-quality images with less radiation.

Computed tomography and CBCT are usually reserved for complex fractures (e.g., comminuted fractures) or in the assessment of fractures of the condyle. They are also undertaken when craniofacial or midface injuries are also present. For most "walking wounded" fractures, plain films are usually adequate (see Figs. 6.7 and 6.8).

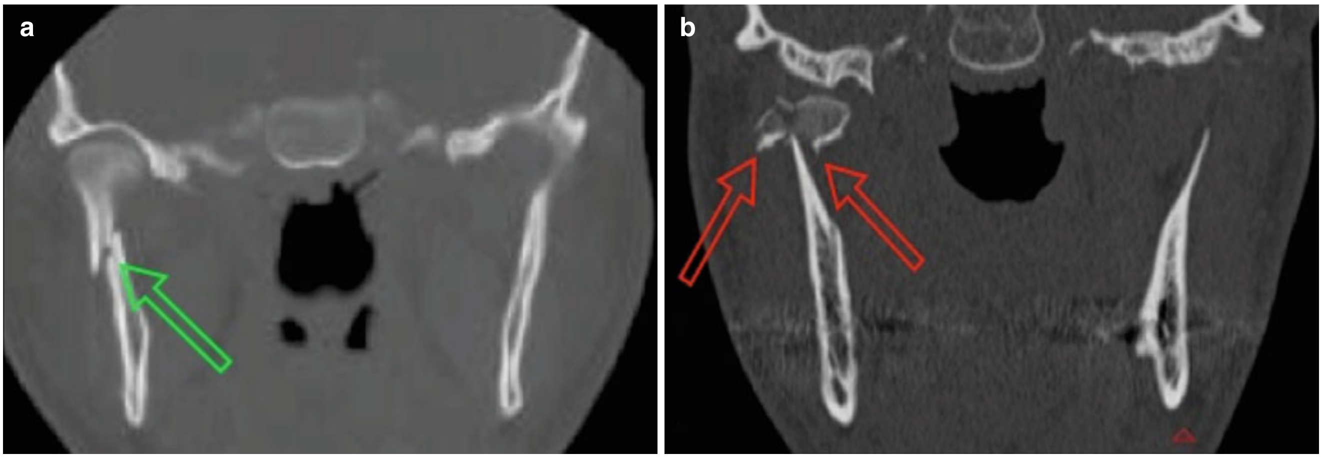

Fig. 6.7 Computed tomography scanning is particularly helpful in assessing complex fractures and those of the mandibular condyle. The *green arrow* in (**a**) shows a simple oblique fracture of the condylar neck, with some telescoping of the fracture. This is a good candidate for surgical repair. Compare this to the *red arrows* in (**b**) showing comminution of the head of the condyle. Access and manipulation of all these fragments would be considerably harder

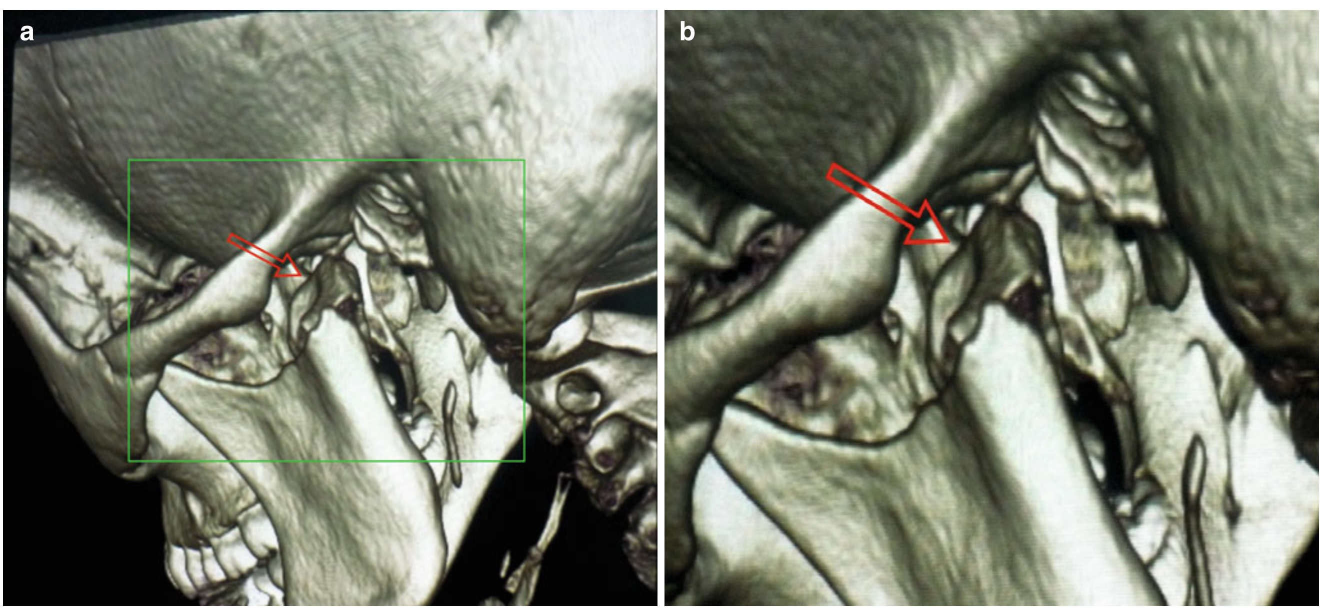

Fig. 6.8 Three-dimensional reformatting helps in planning access. This fracture has resulted in medial dislocation of the head of the condyle (*arrows* in **a**, **b**)

6.4 Common Fracture Patterns

Table 6.3 Common fracture patterns

Symphysis and parasymphysis
Vertical midline fractures of the symphysis can sometimes be relatively stable due to the symmetric pull of the attached muscles (mylohyoid and geniohyoid). However, with oblique fractures, asymmetric pull results in displacement. Bilateral parasymphyseal fractures require considerable force, which usually tears the periosteum. These fractures can then become displaced by the genioglossus. These so-called "bucket handle" fractures can place the airway at risk.
Angle fractures
Depending on the fracture orientation relative to the direction of muscle pull, these have been classified as vertically and horizontally "favourable" or "unfavourable." In unfavourable fractures, the medial pterygoid muscle displaces the posterior fragment lingually, or (together with the masseter) in an upward direction. When this occurs, the periosteum has been ruptured. Bilateral angle fractures are also referred to as "bucket handle" fractures.
Condylar fractures
These are common, either in isolation or in association with other fractures (e.g., "guardsman's" fracture [see text]). "Telescoping" (vertical overlapping) results in premature contact of the molar teeth on the same side. Fracture-dislocation of the condyle (usually medially) usually occurs after high-energy impacts.

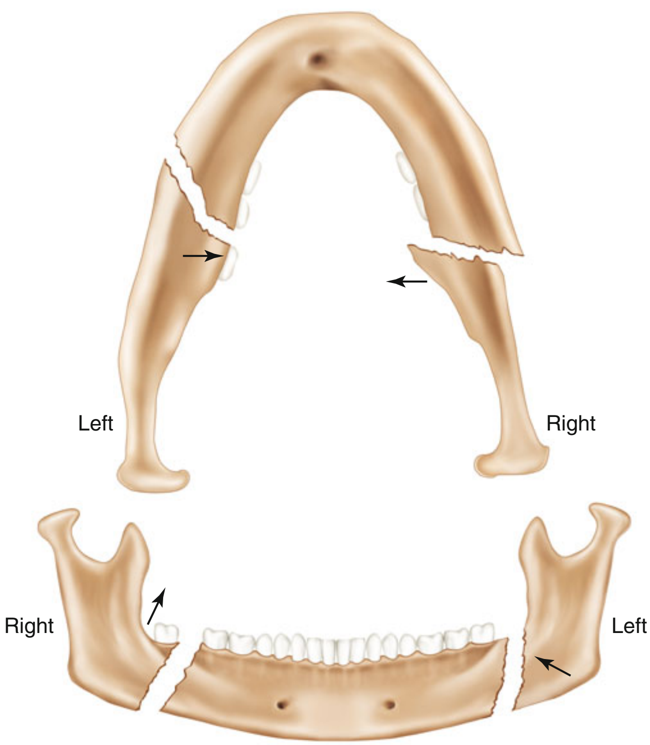

Fig. 6.9 Angle fractures can be described as "favourable" or "unfavourable" depending on the tendency for them to displace secondary to muscle pull. In this diagram, the right side will displace medially and upwards, making it horizontally and vertically unfavourable. On the left side the fracture orientation is such that muscle pull will impact the bones, making this a favourable fracture. This can have a major bearing on the choice of fixation used (number of plates)

Mandible fractures are sometimes described or classified according to their tendency to displace as a result of the pull of the attached muscles. Fractures are said to be "favourable" when the muscles tend to pull the fragments together (minimising displacement) and are "unfavourable" when they are significantly displaced by the muscles. These are further considered as "vertically" or "horizontally" favourable or unfavourable, depending on the direction of displacement. Although this principle can be applied to any part of the mandible where there are muscles attached, it is most commonly used with angle fractures (*see* Figs. 6.9, 6.10 and 6.11).

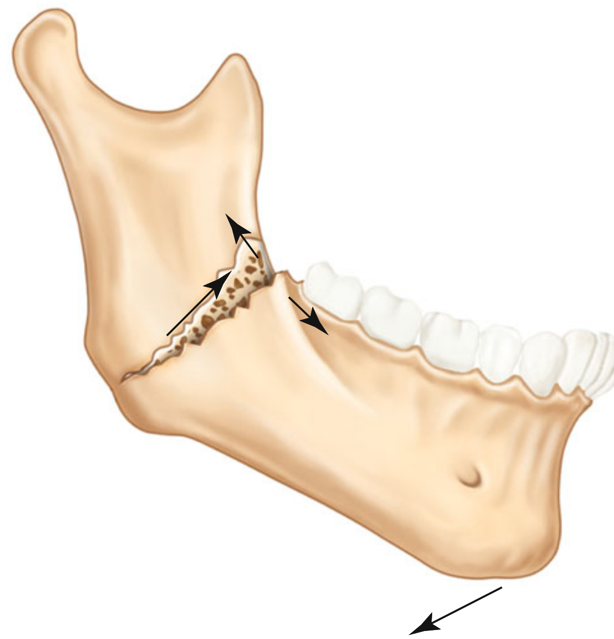

Fig. 6.10 An "unfavorable" angle fracture with displacing muscular forces

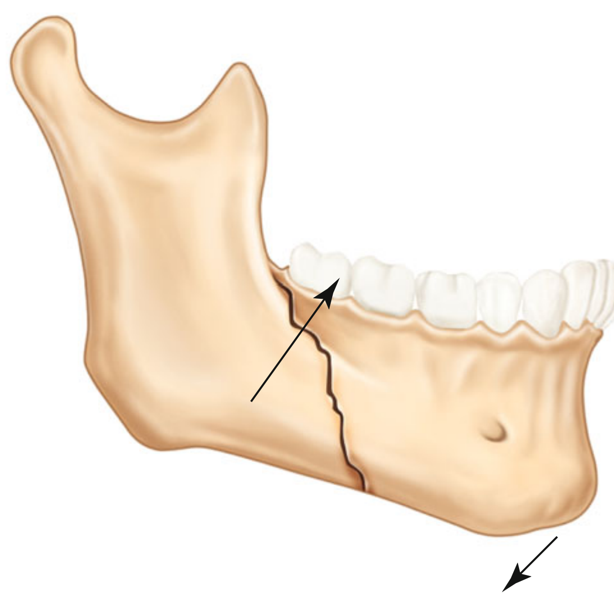

Fig. 6.11 A "favorable" body fracture with muscular forces tending to impact the fracture

6.5 Management

> Acceptable functional outcomes can often be achieved *without the need for precise anatomical* reduction of the fracture.

For most fractures of the mandible, the aim of treatment is primarily to restore function, i.e., to restore both the occlusion and pain-free normal movements in both TMJs. For these goals to be reached, *precise anatomical* reduction is not essential in every case, although it is of course clearly desirable. Because of the relatively thick soft tissue coverage of the jaw, minor discrepancies in nonanatomically reduced fractures are generally imperceptible, in all but the most emaciated of patients. For these reasons, various acceptable treatments still exist, each with varying degrees of anatomical precision. These may be considered within three groups:

1. Intermaxillary fixation (IMF) (also referred to as "closed treatment")
2. Semirigid fixation ("open" treatment; i.e., exposure of the fracture is required)
3. Rigid fixation ("open" treatment)

6.5.1 IMF Versus Open Treatment

In many patients, all the requirements for successful fracture treatment (adequate reduction, stabilisation, rehabilitation, and minimal complications) can be reliably achieved by both "closed" and "open" treatments. Which is used depends on a number of factors (e.g., surgeon's/patient's preference, medical history, smoking, local infection).

6.5.1.1 Undisplaced and Minimally Displaced Fractures

In undisplaced fractures, "closed" treatment simply involves analgesia, judicious use of antibiotics (if the fracture is contaminated), and a soft diet until a firm callus has formed (usually around 4–6 weeks). IMF during this time may or may not be required. Indications for closed treatment are shown in Table 6.4.

Where fractures are very minimally displaced and also not too mobile, surgical treatment can sometimes be avoided, so long as the patient is motivated, fully compliant, and can be reviewed closely. In these cases, outcomes are often good, although there is always a risk of increasing movement and displacement occurring at the fracture site, necessitating repair.

In other cases, IMF may be used to immobilise the fracture, provide pain relief, or to provide additional support following surgical repair. This is also closed treatment and works well in those minimally displaced fractures that are clinically stable. These patients tend to have minimal changes in their occlusion. Ideally the fracture pattern should be "favourable," but this is not essential. At approximately 1 month, most simple fractures should have healed sufficiently to allow the patient to return to a normal diet. For obvious reasons, IMF must be used with care in certain groups of patients (epileptics, alcoholics, respiratory disease) (see Fig. 6.12).

Table 6.4 Indications for closed treatment (Soft Diet, Antibiotics, ±IMF)

No or minimal displacement of a stable fracture
No or minimal mobility across the fracture line
No impairment of function
Ability to obtain preinjury occlusion
Good patient cooperation and follow-up
Patient refuses ORIF (consider IMF)
Lengthy surgery is required, but is not possible (patient is too unstable). Consider IMF.

> Closed treatment does not reduce fractures anatomically—it is wrong to assume that just because the teeth meet, the fractures are in the anatomically correct position.

6.5.1.2 Displaced Fractures

If the fracture is significantly displaced or mobile, then either closed IMF or open treatments may be undertaken. As a temporary measure (if the fracture can be reduced manually), a "bridle" or tie wire should be placed around the adjacent teeth. This reduces the fracture and provides temporary support, thereby reducing painful movement (see Fig. 6.13).

Bridle wires are effectively the maxillofacial equivalent of an orthopaedic backslab used to support limb fractures. By itself, or sometimes combined with IMF, a tie wire should always be considered when significant delays in repair are anticipated (i.e., surgery the next day). Loose dentoalveolar fractures can also be temporarily splinted with this technique. Some clinicians prescribe antibiotics if the fracture involves a periodontal socket (making it technically compound, or open).

Open treatment is now commonly undertaken for many displaced fractures. Surgical exposure enables precise anatomical reduction and firm fixation of the fracture site. Currently there are two schools of thought when undertaking open fixation of mandibular fractures (see Table 6.5).

In many centres today, transoral semirigid ("miniplate") fixation is commonly undertaken for most "routine" mandibular fractures, thereby avoiding the need for external

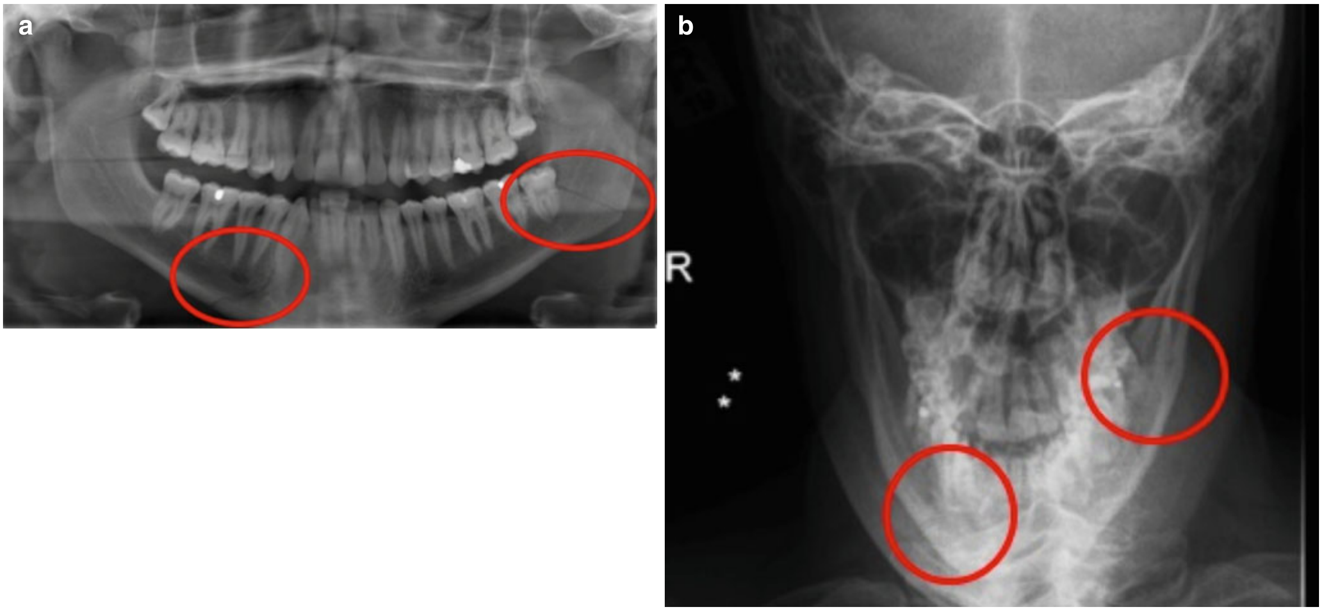

Fig. 6.12 (**a**, **b**) Bilateral minimally displaced fractures. Although ORIF would be an acceptable treatment modality, their alignment is good and there is minimal mobility across the fractures. This case could be managed with soft diet alone, but would need close follow-up. Alternatively, IMF could be applied. All are acceptable treatments

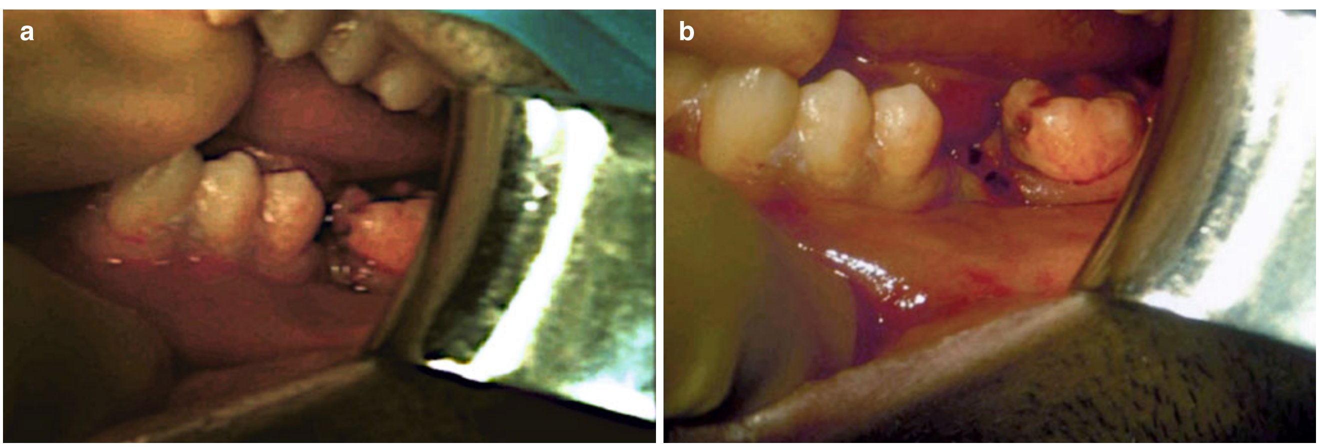

Fig. 6.13 Fracture mobility cannot be determined on a radiograph—the patient must be carefully examined. Although a fracture may appear to be minimally displaced, it can still move. Significant movement such as shown here (**a**, **b**) needs support (IMF or ORIF)

Table 6.5 Management philosophies in open repair of mandibular fracture(s)

Rigid fixation is required	Only semirigid fixation is required
Quicker return to normal function	Requires soft diet ± IMF postop
Reliable	Small risk of infection
Strong plates	Smaller plates
Requires extraoral approach	Can be placed through the mouth
Bicortical screws risk ID nerve and teeth	Monocortical screws have less risk
Technically demanding	Easier technique
Second procedure to remove plate	Plates can be left

incisions and heavy plates. *Elastic* IMF, may still be required to “fine tune” the bite (if anatomical reduction was not possible), but wire IMF is now rarely indicated as definitive treatment. Elastic IMF also provides additional support to the fracture postoperatively. Rigid “load-bearing” fixation still has a significant role to play and is often reserved for complex cases (e.g., extensive comminution, infected fractures, or when immediate bone grafting is required). It is also used when semirigid fixation has failed (see Fig. 6.14).

Displaced or mobile fractures can therefore be managed in a number of ways (see Table 6.6).

Each of these options has specific advantages and disadvantages compared with the others. When fixation is required, the final choice depends on the site and type of fracture, condition of the overlying soft tissues, the patient’s general condition and preferences, resources available, as well as the personal preference and technical skills of the surgeon. Generally speaking, open treatments tend to be used when closed treatment is inappropriate or has failed (see Figs. 6.15, 6.16, 6.17 and 6.18).

6.5.2 Surgical Repair (Open Treatment)

Interestingly, the first descriptions of mandibular fractures came from the Egyptians in 1650 BC. Hippocrates is also reported to have described the treatment of a fractured mandible using circumferential wiring. Today, surgical repair requires the following steps.

1. Establishing access (through an incision or overlaying wound)
2. Reestablishing the patient’s occlusion (with temporary IMF)
3. Anatomical reduction of the fracture(s)
4. Fixation
5. Closure

Steps 2 and 3 are sometimes interchangeable, depending on the fracture configuration. With good assistance in relatively straightforward cases, on-table IMF can usually be achieved by simply holding the teeth together manually. However, this is not recommended for the novice, or when operating without assistance.

Table 6.6 Treatment options for displaced or mobile mandibular fractures

Closed treatment
With wire or elastics
Open treatment (direct exposure of the fracture through wound or incision)
ORIF via a transoral approach (semirigid)
ORIF via a transcutaneous approach (rigid)
External fixation

Fig. 6.14 “Load sharing” or “miniplate” fixation is now a common method of surgical repair. In this case it has been supplemented with IMF screws (Note the high position of the plate. This is discussed later)

Fig. 6.15 IMF can take many forms. In this case, circumdental wires are shown

Fig. 6.16 Here, circumdental wires are combined with a custom-shaped arch bar

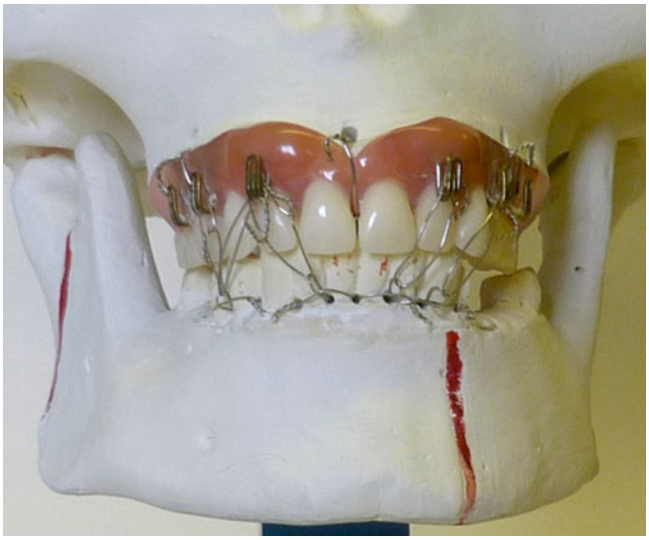

Fig. 6.17 If the patient is edentulous, the denture can be adapted (provided it is a good fit). This can be wired or screwed to the hard palate

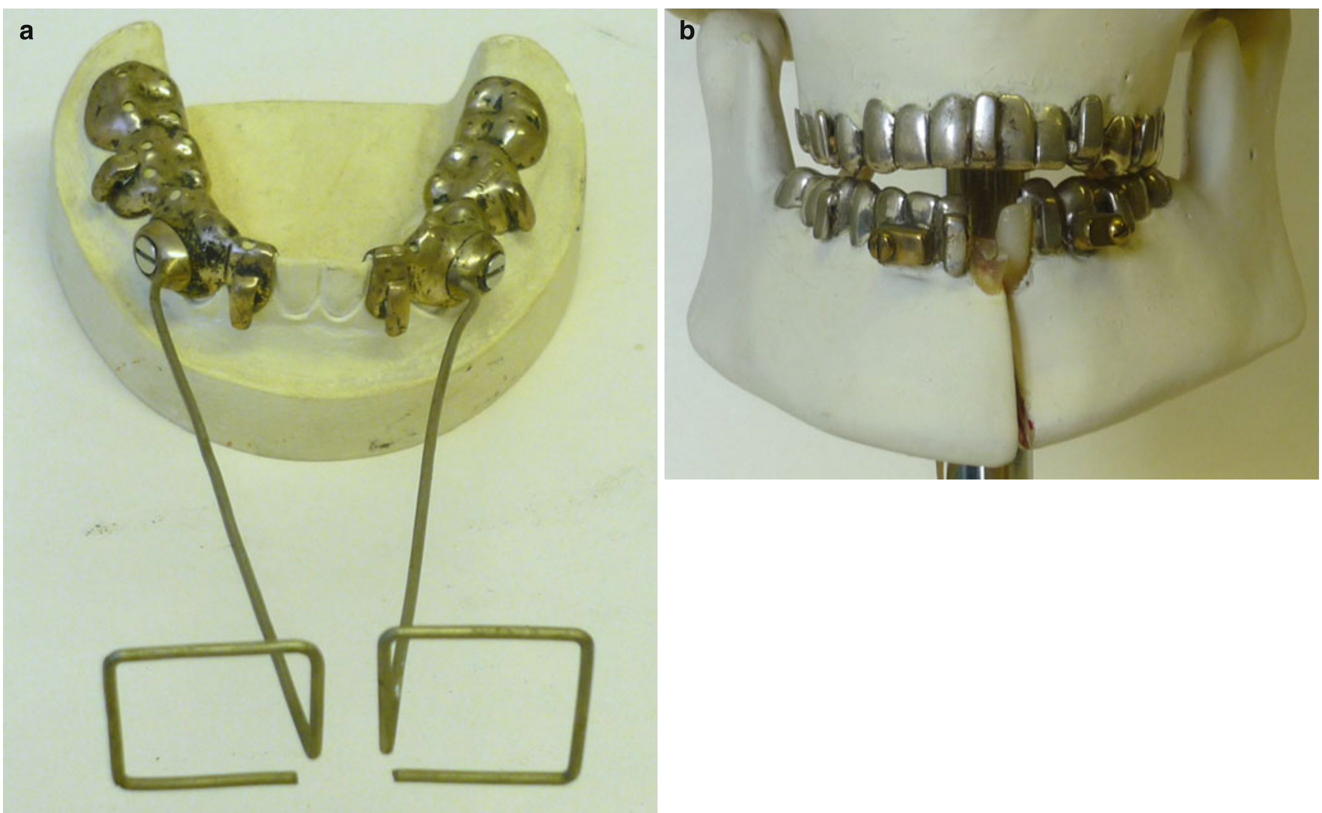

Fig. 6.18 Perhaps more of historical interest, cast metal cap splints can be fabricated from dental models and cemented to the teeth (**a**, **b**). IMF will then gradually reduce the fracture and support it. Alternatively, a "locking bar" can hold the lower arch splints in the reduced position

6.5.2.1 Transoral "Miniplate" Repair (Adaptive Osteosynthesis)

Most fractures involving the mandibular symphysis, parasymphysis, body and angle can be adequately exposed through the mouth, thereby avoiding the need for visible external scars. Several well-known approaches exist. As a general principle, whenever possible, place incisions at least 5 mm from the mucogingival junction. This avoids damaging the attached gingiva and periodontal tissues, minimising the risk of dehiscence and gingival recession later.

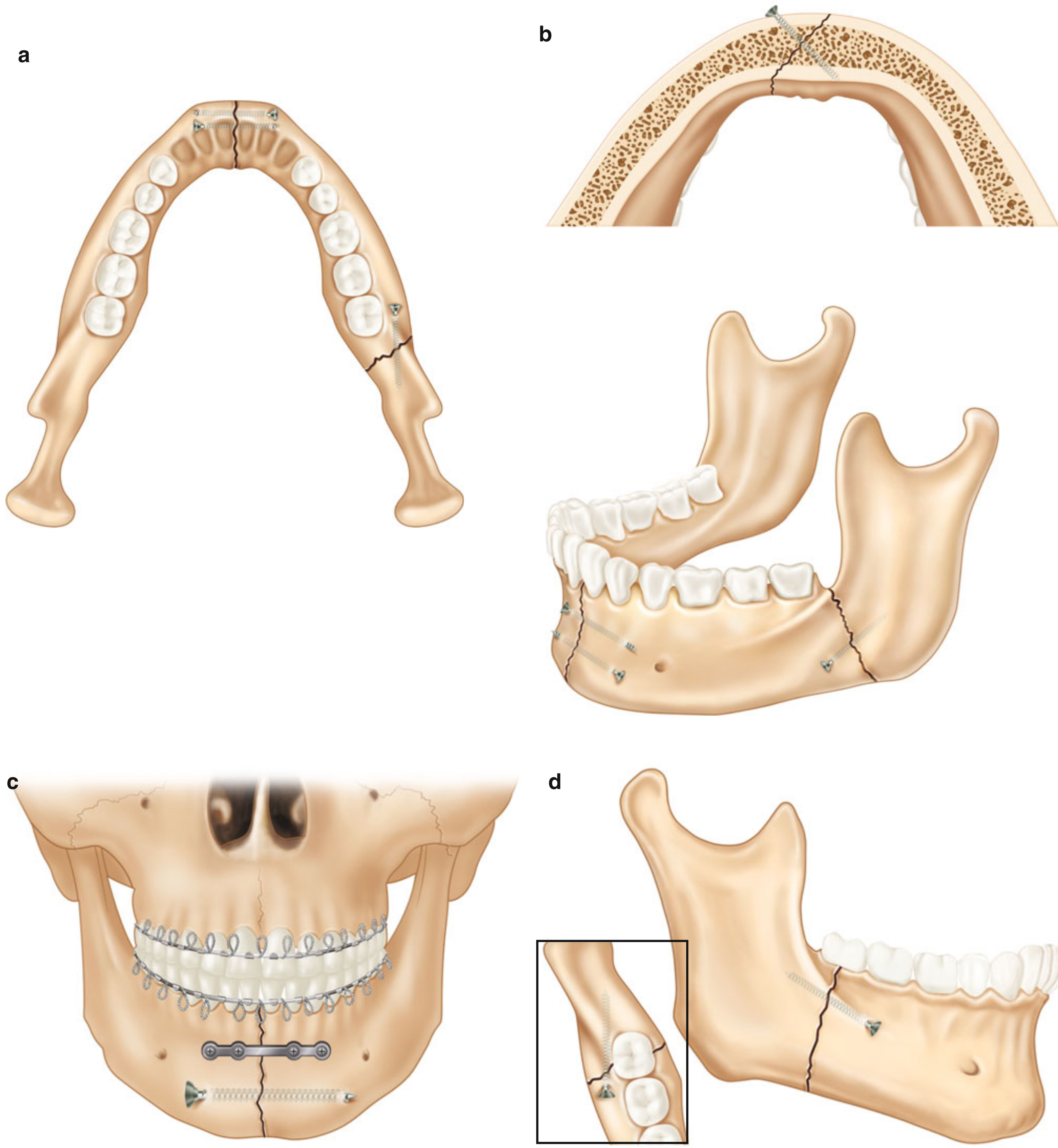

Fig. 6.19 Lag screws. These can occasionally be used to support fractures. The fracture orientation must be clearly defined. Screws should ideally be placed at 90° to this, so this is not a technique suitable for all fractures (**a**–**d**)

Sometimes lag screws are used in the management of mandibular fractures instead of plates. The general principles and technique of lag screwing is described elsewhere, but the aim is to place one or two screws across the fracture, ideally at a right angle. The advantages of this technique are that it is a relatively quick procedure and requires minimal access. However, this is also a very technically demanding procedure and as such is a specialised area of practice. Case selection is very important, paying particular attention to the fracture configuration. Specialised views of the fractures may be required (see Fig. 6.19).

Anterior Fractures (Symphysis/Parasymphysis)

Access to the anterior mandible can be undertaken in several ways. The traditional gingival crevicular incision with elevation of a full-thickness mucoperiosteal flap is perhaps less commonly used today. Although it is quick and easy to raise, access to the lower border of the mandible can be difficult, and excessive traction on the flap can result in traction on the mental nerves. Precise closure of this wound is also difficult and carries a risk of dehiscence and gingival recession (see Fig. 6.20).

Fig. 6.20 Gingival crevicular incision

Alternatively, a stepped, two-layer approach may be used. This requires an initial full-thickness mucosal incision on the inside of the lower lip approximately 1 cm from the depths of the labial sulcus. Before incising, look carefully. Very often, terminal branches of the mental nerves can be seen running below the mucosa. The incision is therefore made delicately as these nerves are often quite superficial (see Fig. 6.21).

Following incision, any nerves are quickly identified and protected. Minor salivary glands are also frequently encountered, as they herniate through the edges of the incision. These are simply removed if they get in the way. Mucocele formation does not appear to be a problem. A small flap is then raised in the submucosal plane. The underlying orbicularis oris is incised, leaving a small cuff of muscle attached to the upper periosteum. This will facilitate closure of the deeper layer. The periosteum is then incised and elevated to expose the lower three quarters of the mandible down to the lower border. Depending on the precise location of the fracture and the exposure required, one or both mental nerves may be encountered as they leave the mental foramen. It is important not to retract too hard, as this can result in traction injury. Although the upper periosteum can also be raised, care is required in doing this, so as not to completely detach the upper gingival cuff (see the following case examples).

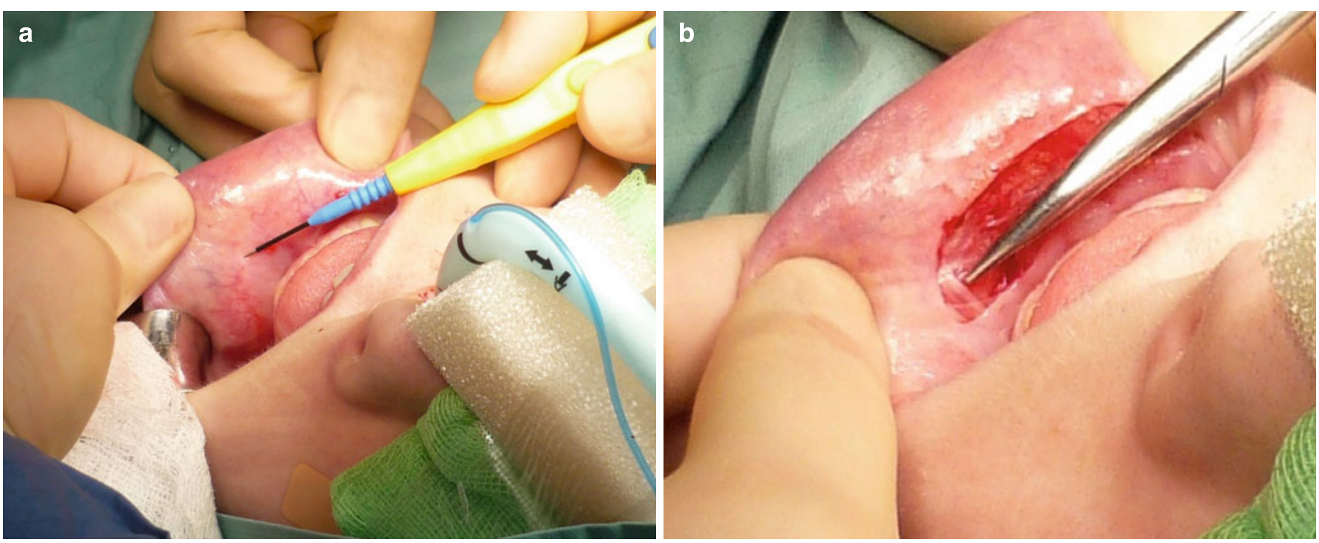

Fig. 6.21 Always look carefully before making an incision (**a**). Often some of the terminal branches of the mental nerve can be seen running under the mucosa. These can be easily damaged when making the incision. One such branch is shown in (**b**)

Case 1

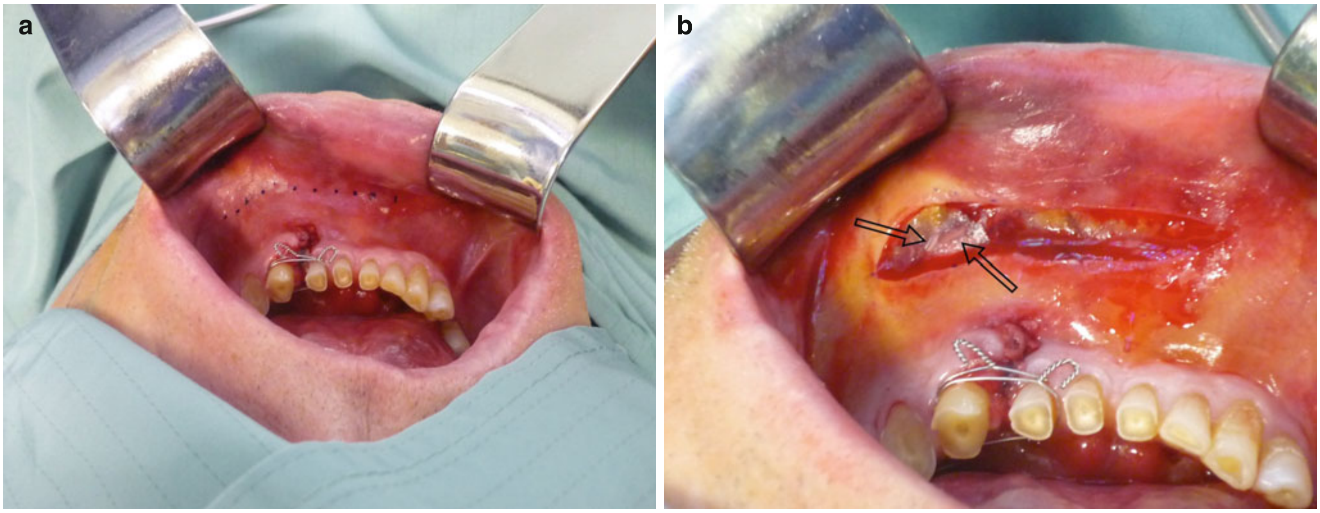

Fig. 6.22 Following an initial mucosal incision (**a**), the terminal branches of the mental nerve are quickly identified (**b**)

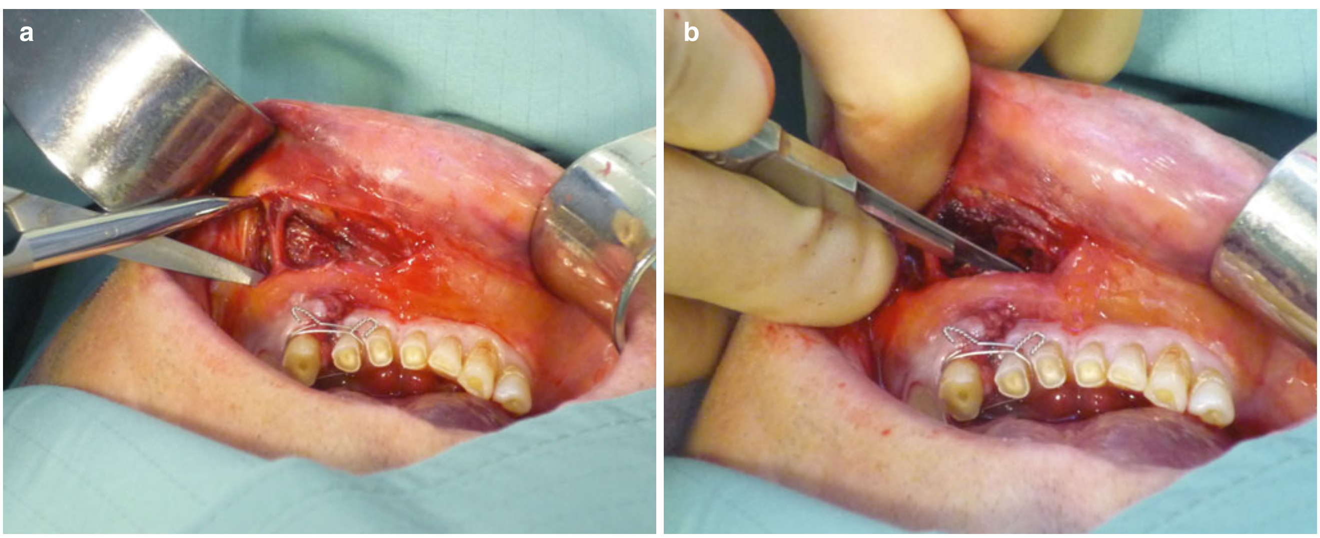

Fig. 6.23 Careful dissection isolates the nerve (**a**). This is protected throughout the procedure. A second periosteal incision is made (**b**)

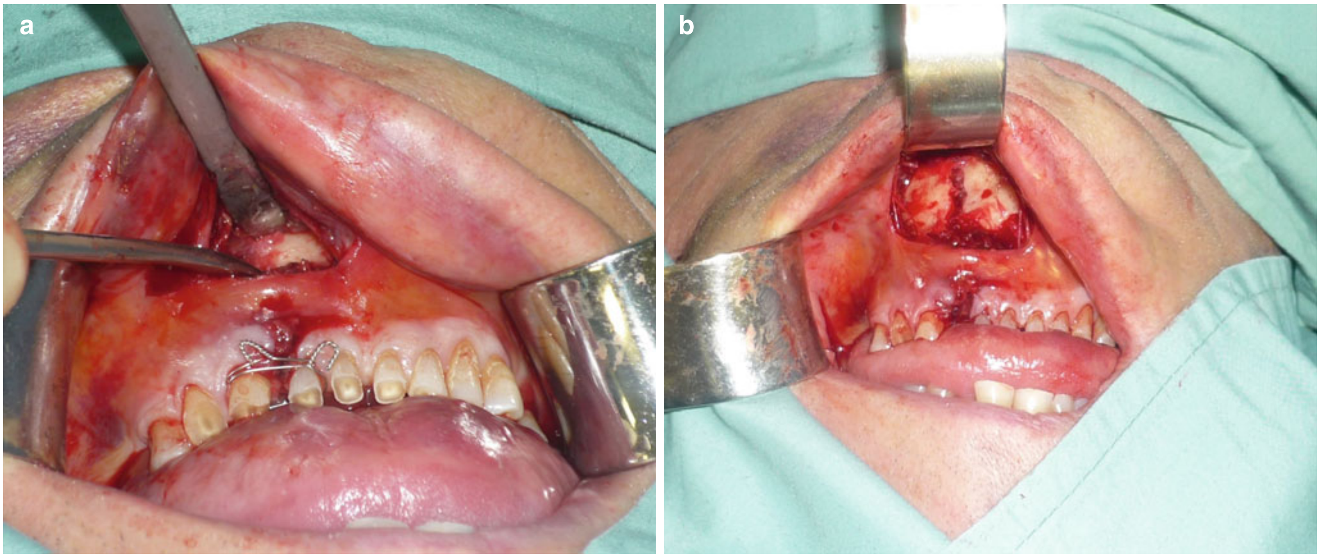

Fig. 6.24 Periosteal elevation (**a**) exposes the anterior fracture (**b**)

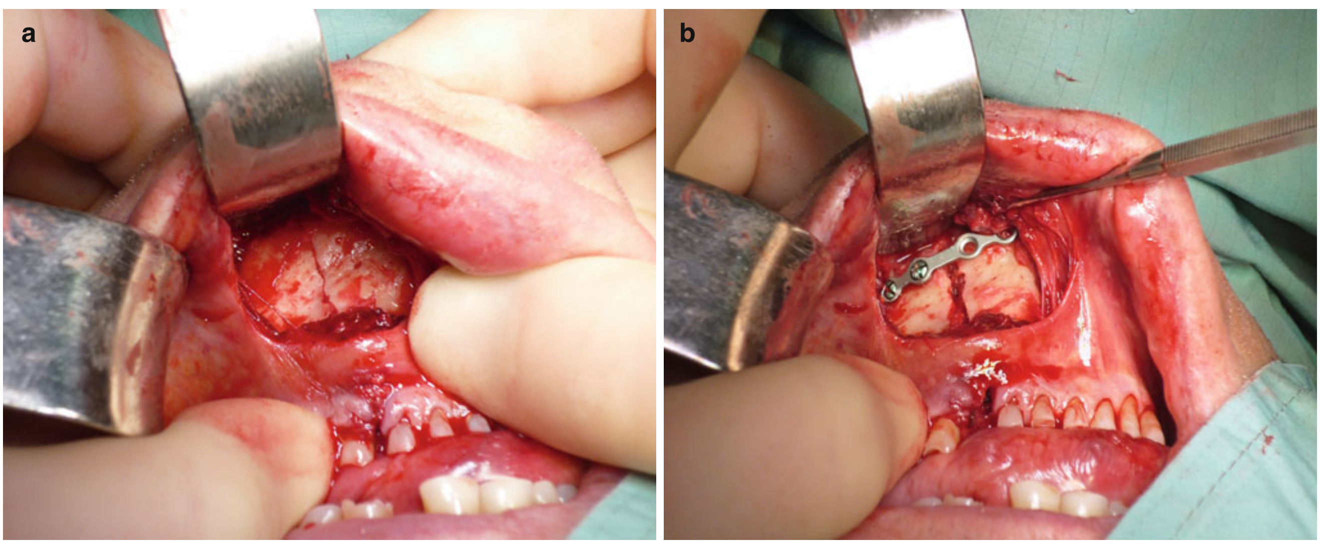

Fig. 6.25 The fracture can be easily manipulated into the reduced position (**a**). It is then plated (**b**)

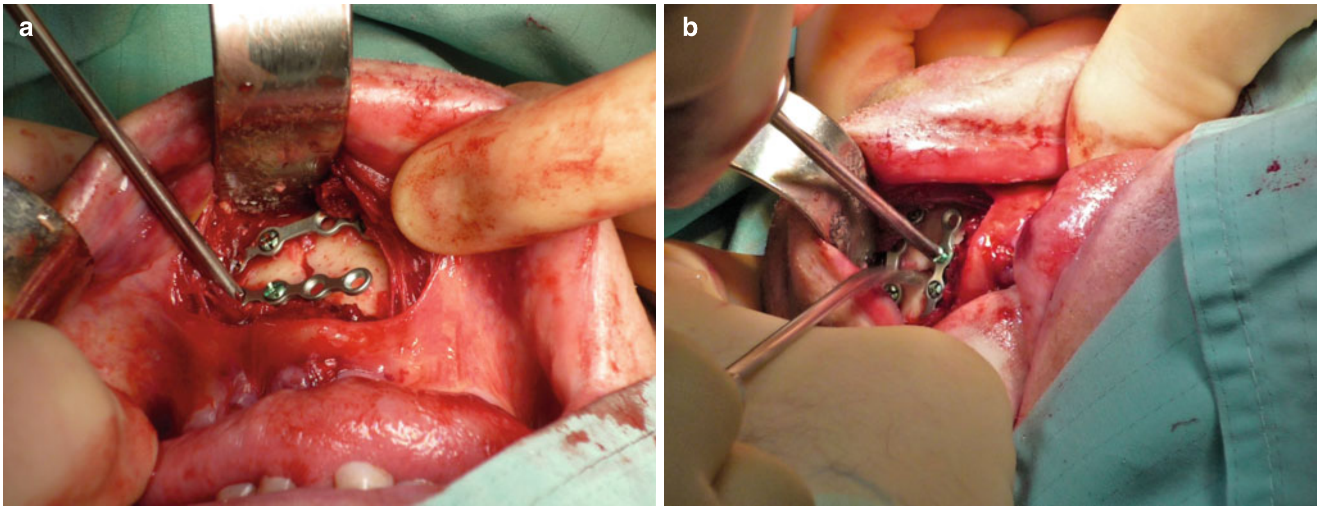

Fig. 6.26 Depending on assistance, sometimes it is easier to secure the plate(s) on the distal fragment first, then reduce the fracture and secure it on the proximal fragment (**a**, **b**). Other sequences exist

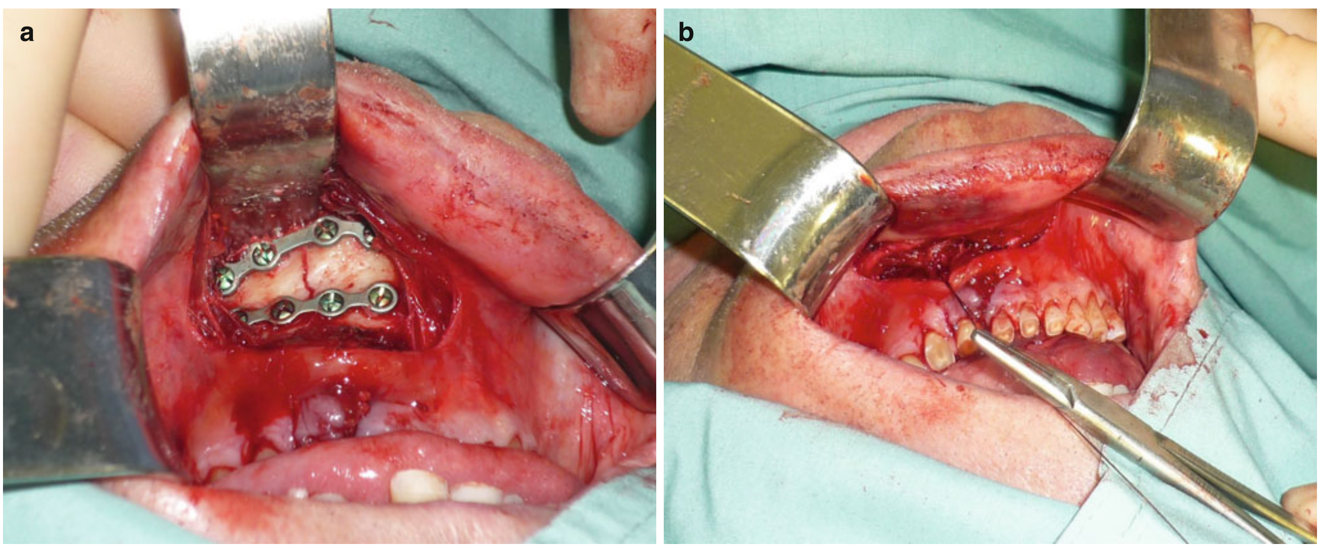

Fig. 6.27 Following repair (**a**), the wound is closed in layers (**b**)

Case 2

This follows the same steps as case 1 (see Fig. 6.28).

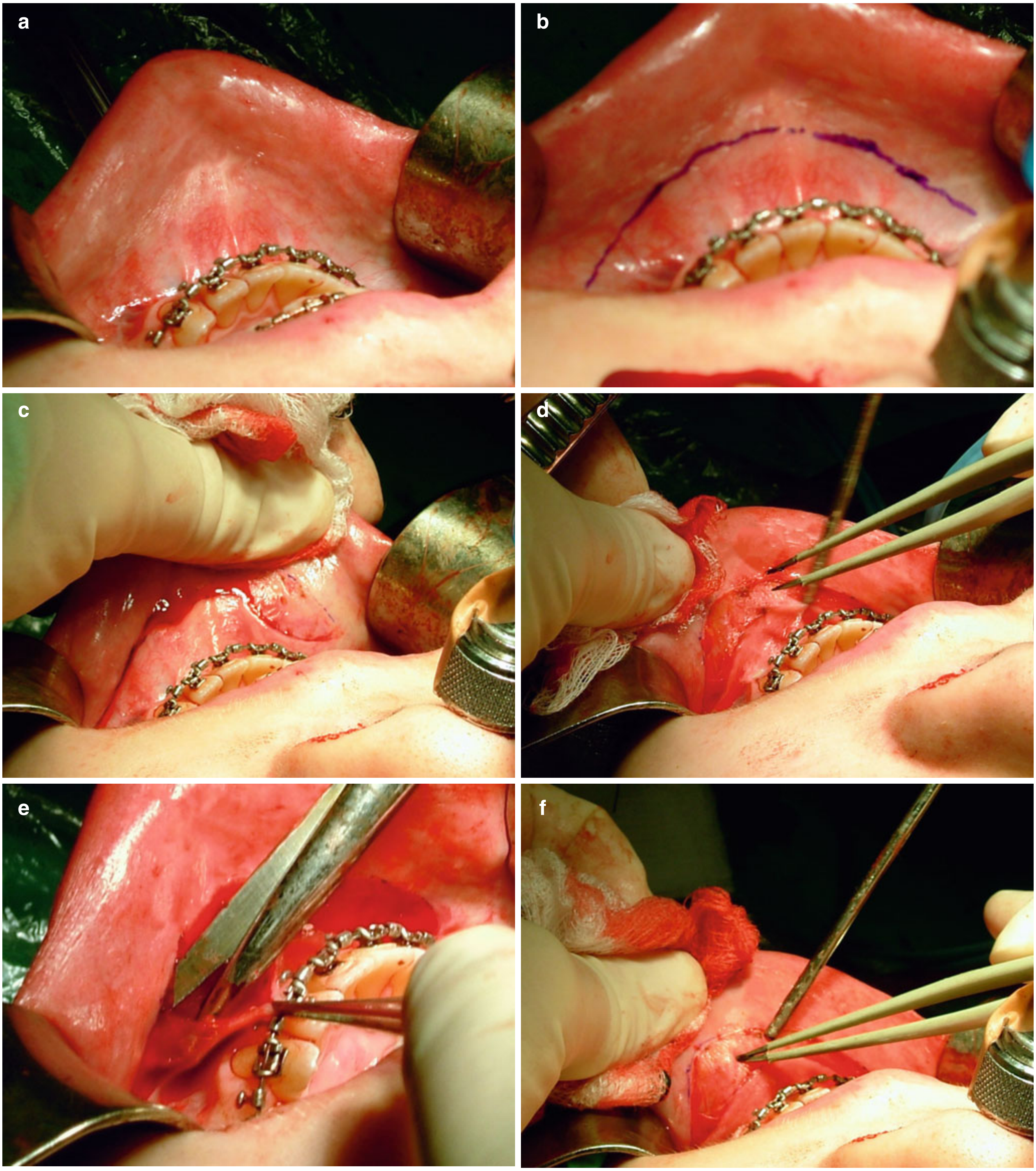

Fig. 6.28 (**a**–**i**) This follows the same steps as Case 1. The two-layer approach leaves a small cuff of muscle attached to the upper periosteum. This facilitates a two-layer, watertight closure and supports the wound postoperatively (**j**). Poor closure can result in chin ptosis

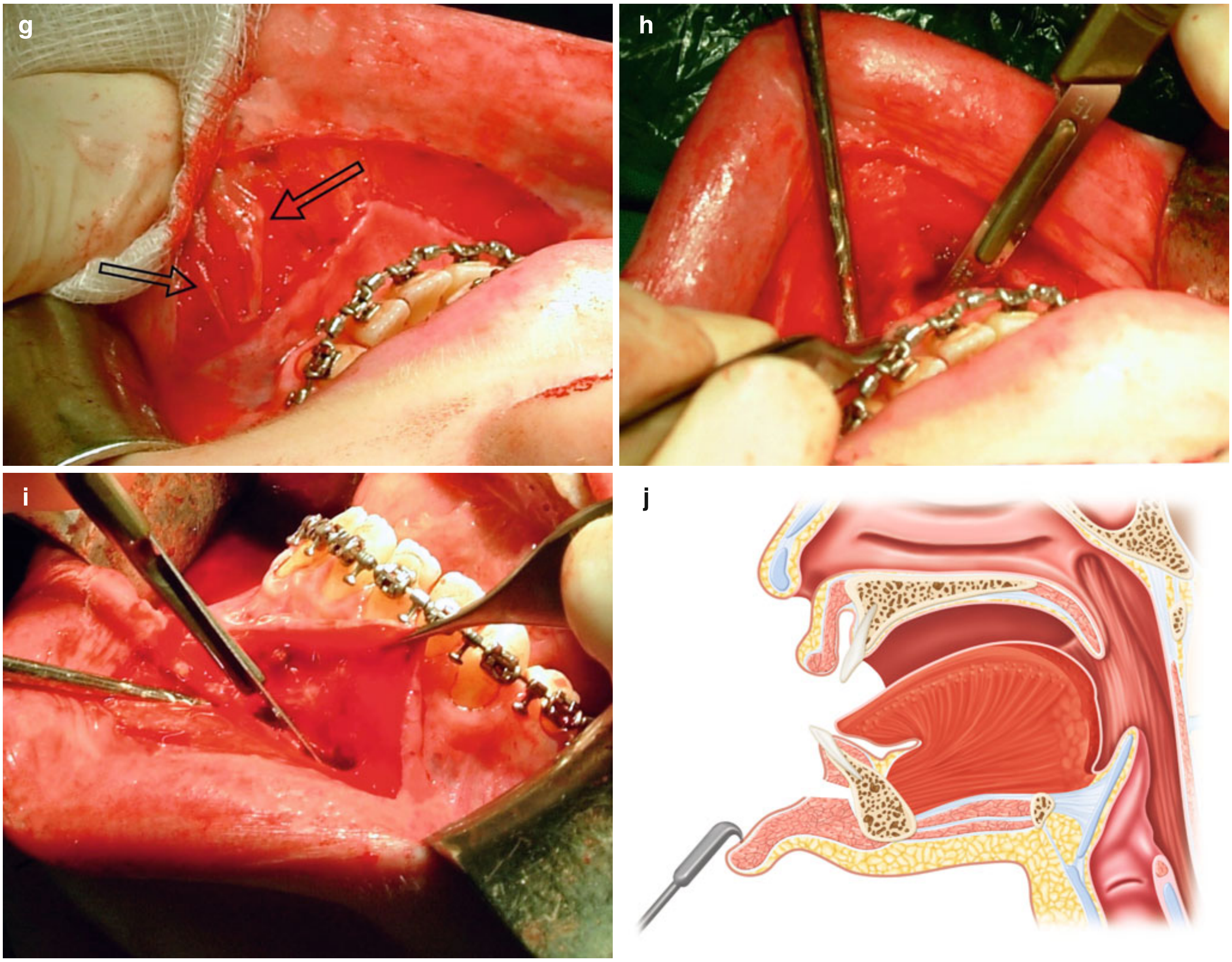

Fig. 6.28 (continued)

Case 3

This follows the same sequence as case 1 (see Fig. 6.29).

Following fracture repair, the wound is closed in layers. The muscle layer is closed using interrupted long-lasting resorbable sutures, and the mucosa using a continuous resorbable suture. It is important that the periosteum and muscle reattach and heal in the correct position. Failure to do so results in sagging of the overlying soft tissues and chin ptosis. A supportive dressing for 10 days postoperatively helps support the soft tissues.

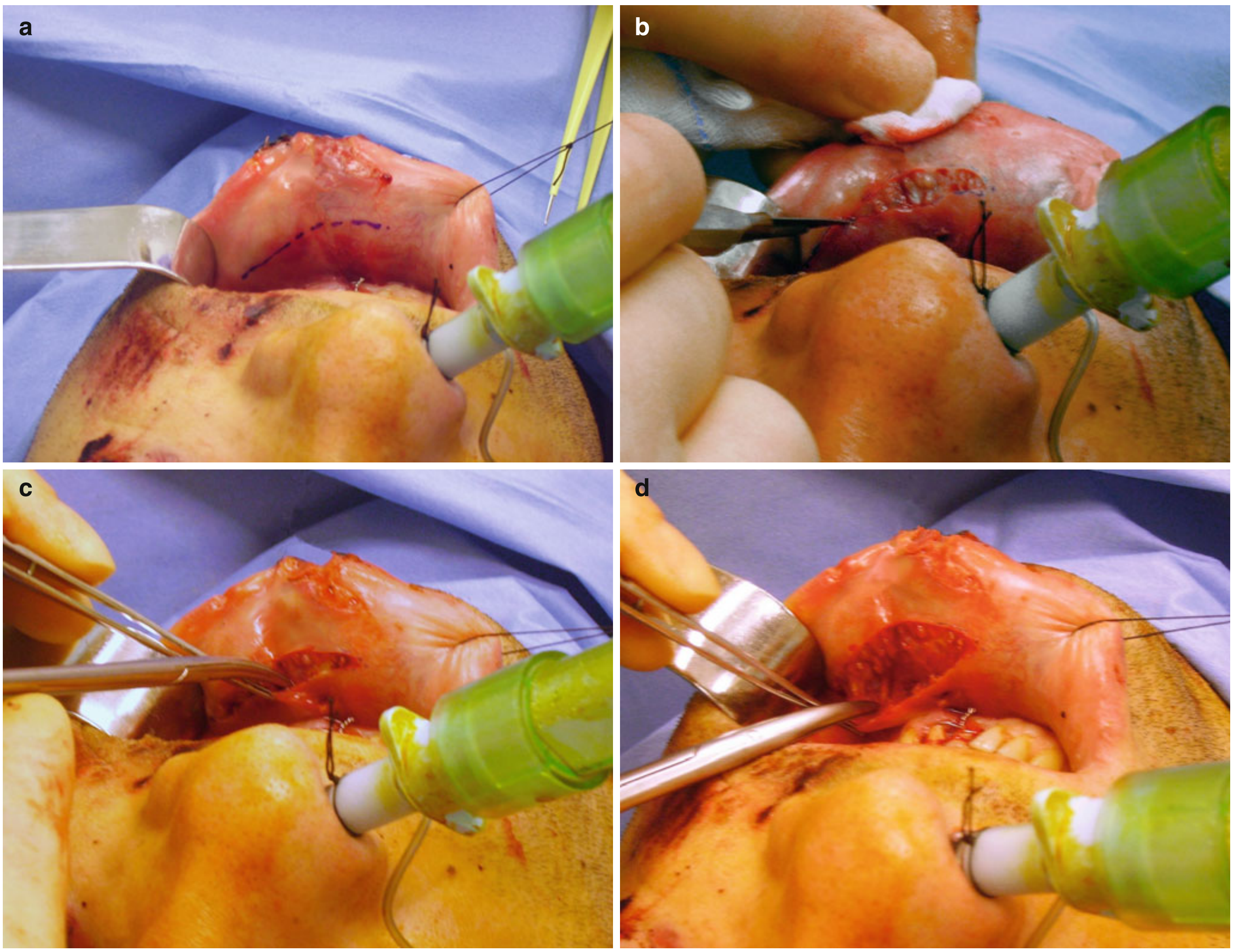

Fig. 6.29 (**a**–**f**) This follows the same steps as Case 1. The mental nerve can be seen exiting the foramen (**g**). Parasymphyseal fractures often run close to this site

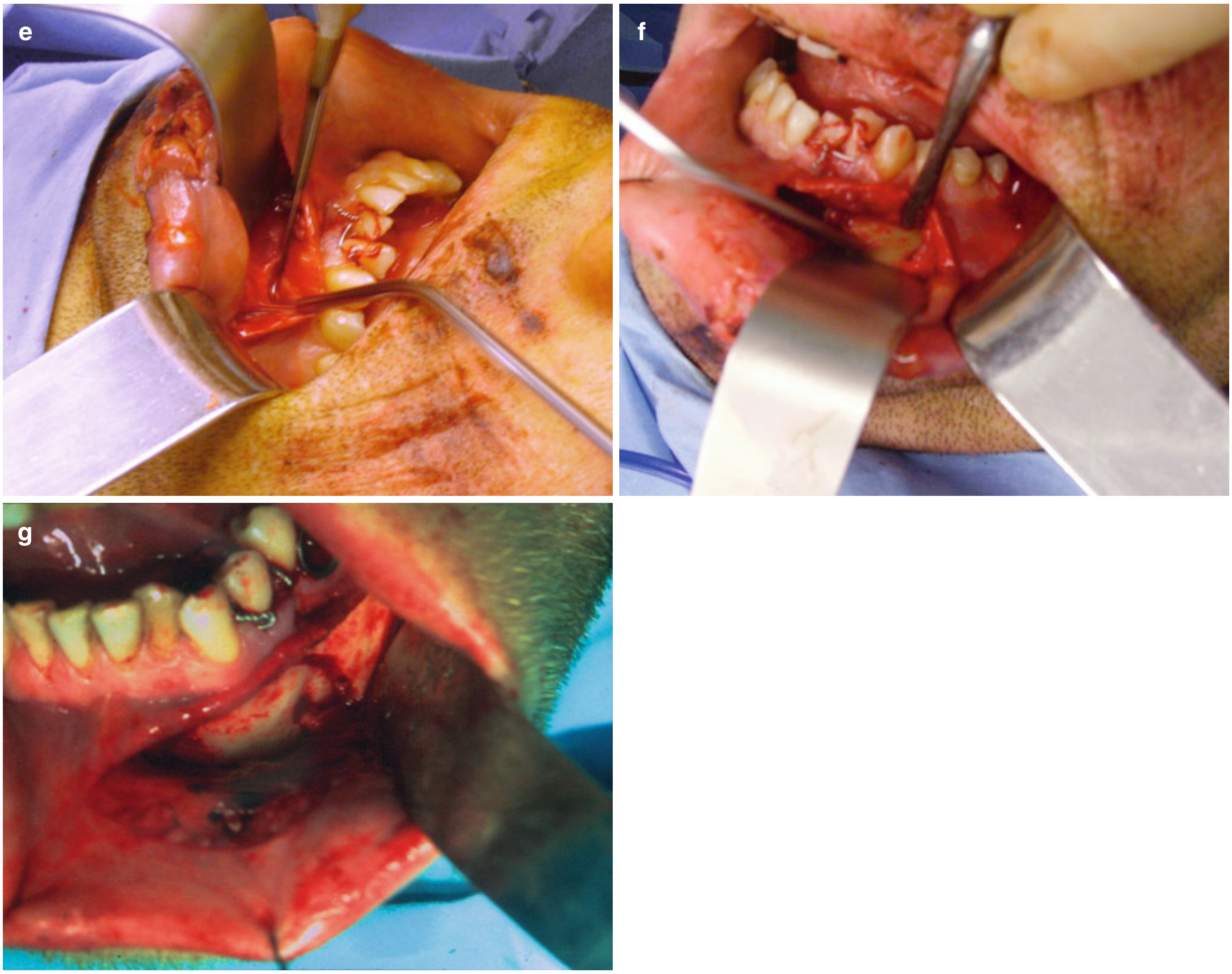

Fig. 6.29 (continued)

Case 4

See Fig. 6.30.

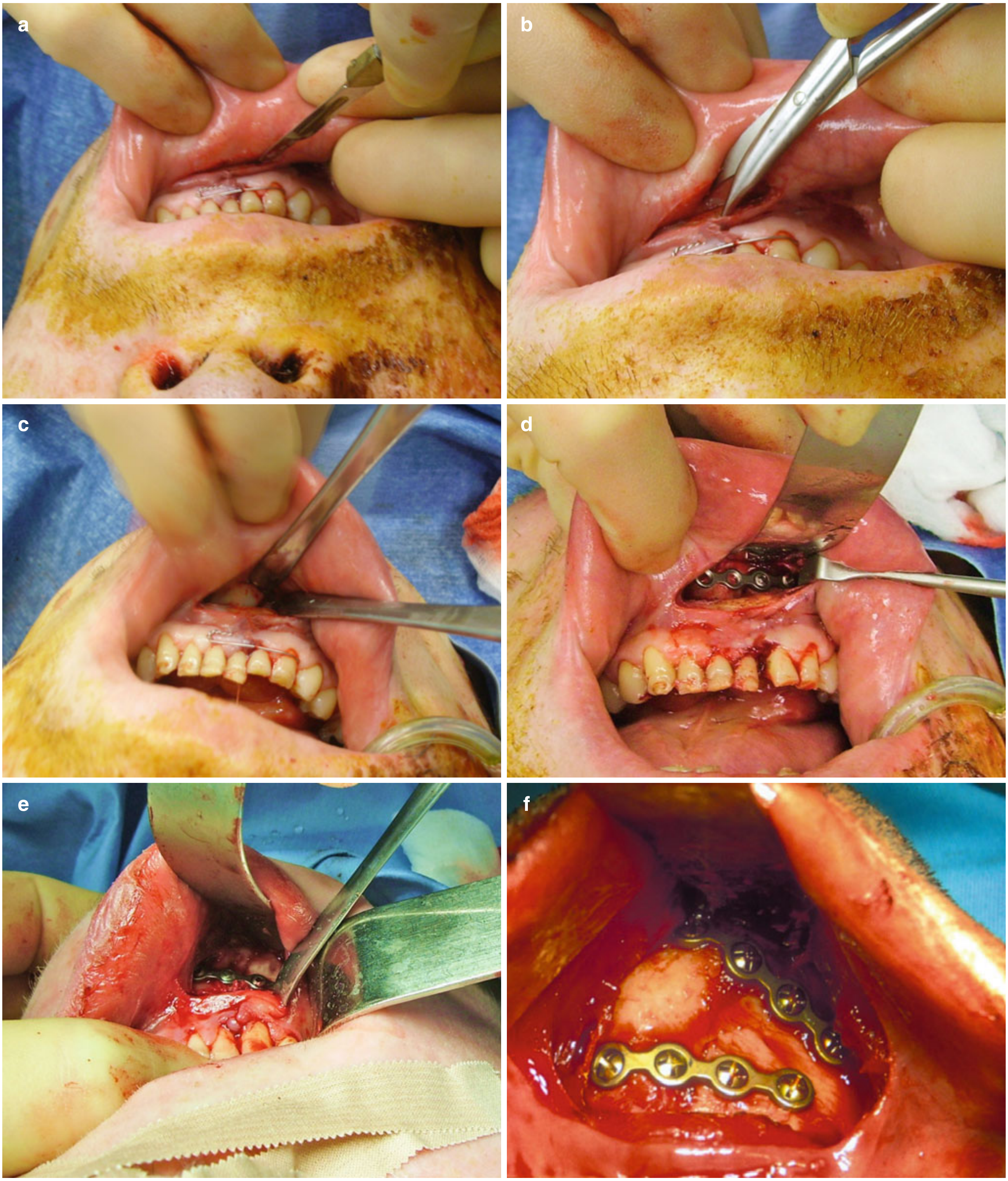

Fig. 6.30 (**a**–**d**) In this case, a single layer approach has been used. The incision has been placed 5 mm below the mucogingival junction, straight down to bone

Posterior Fractures (Body/Angle)

More posteriorly, the ramus, angle, and body of the mandible can be approached through a one-layer vestibular incision. A gingival crevicular incision may be used but is subject to the same problems as with the anterior mandible (see Fig. 6.31).

Alternatively an incision starts at the lower end of the external oblique ridge passing anteriorly, maintaining a 5-mm cuff of tissue below the mucogingival junction. Full-thickness mucoperiosteal flaps are then elevated to visualise these areas.

Other variants of these approaches exist, but whichever is used, all enable the direct visualisation and placement of plates across most mandibular fractures (see Figs. 6.32–6.38).

How Many Plates Are Required?

Controversy currently exists in the management of angle fractures. With the development of the percutaneous trocar technique, plates can now be placed at sites "deeper" than was previously possible through the mouth, for example along the condylar neck and lower border of the mandible. This has resulted in two further schools of thought in the management of angle (and some body) fractures.

1. Two "deeper" plates (one above and one below the ID canal) will result in stronger fixation. They also maintain anatomical reduction, as the lower plate maintains correct alignment of the lower border. It is reported that there is less risk of infection (see Fig. 6.43).
2. One plate along "Champy's" line is perfectly adequate. Perfect anatomical reduction is not necessary. Any minor displacement along the lower border will not be clinically significant as the masseter muscle will cover it. This is a simpler procedure and carries less risk to both the ID nerve and buccal branch of the facial nerve. If the plate gets infected it can easily be removed transorally (see Figs. 6.44 and 6.45).

With the percutaneous trocar technique, drilling and screw placement requires a small skin incision in the lateral cheek, through which the trocar is passed. However, in selected cases this technique also enables larger rigid fixation plates to be placed transorally (see Figs. 6.46, 6.47, 6.48, 6.49 and 6.50).

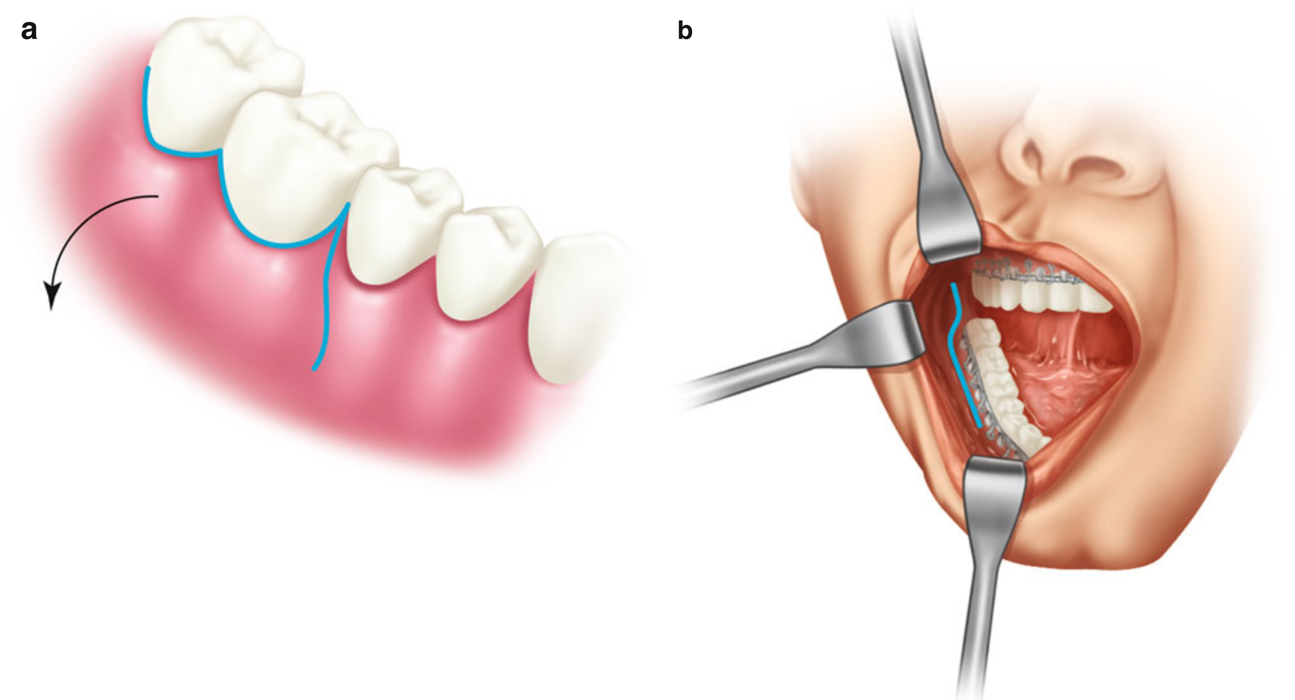

Fig. 6.31 Surgical approaches to the posterior mandible

Case 1

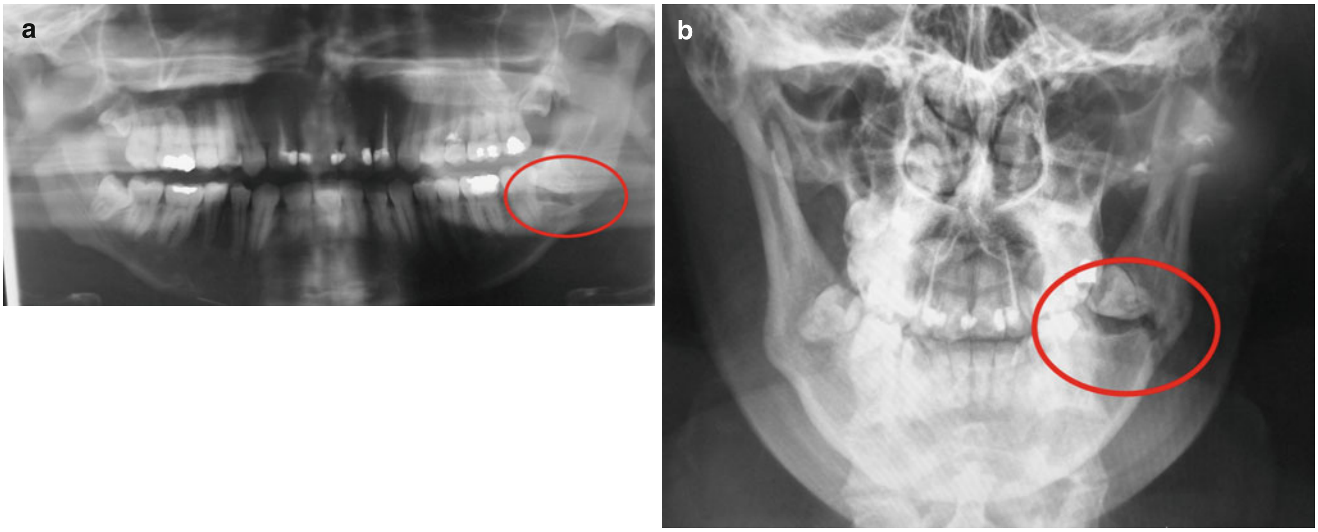

Fig. 6.32 (**a**, **b**) Displaced left angle fracture

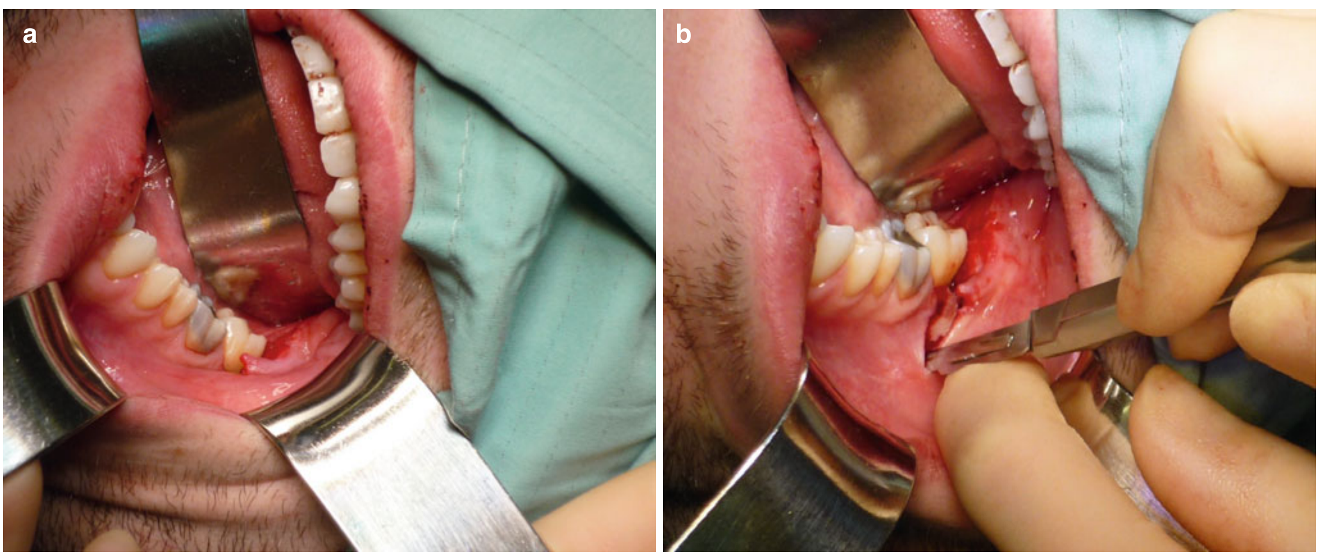

Fig. 6.33 The mucosa had already been torn by the fracture (**a**). The tear was extended 1 cm into the buccal mucosa (**b**)

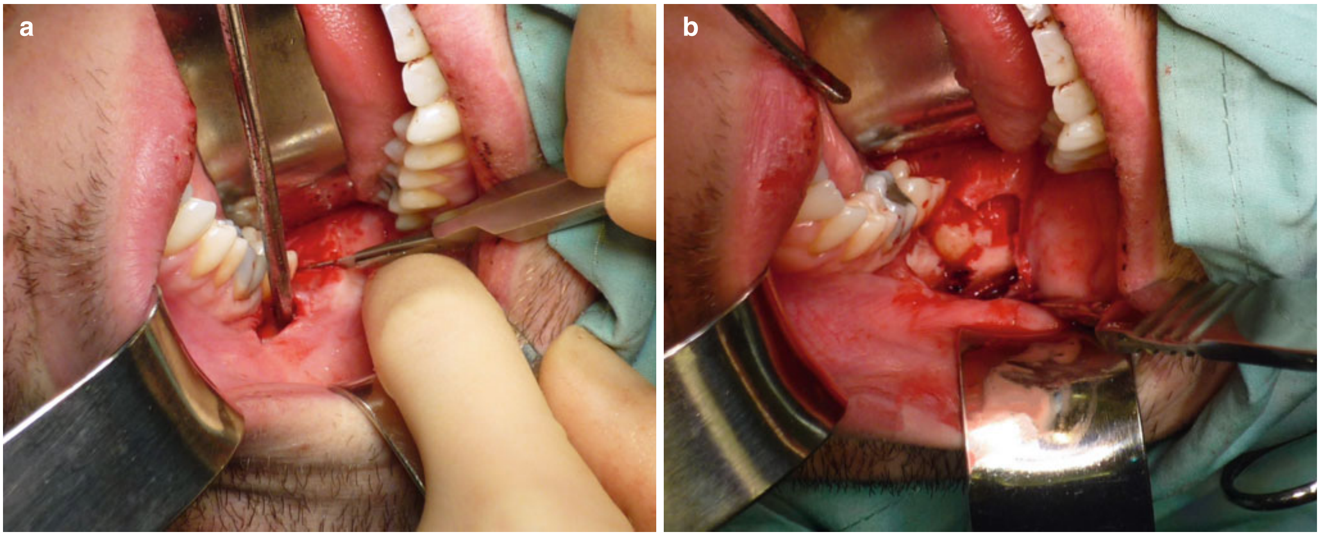

Fig. 6.34 A distal relieving incision was placed (**a**) and a full-thickness mucoperiosteal flap raised (**b**)

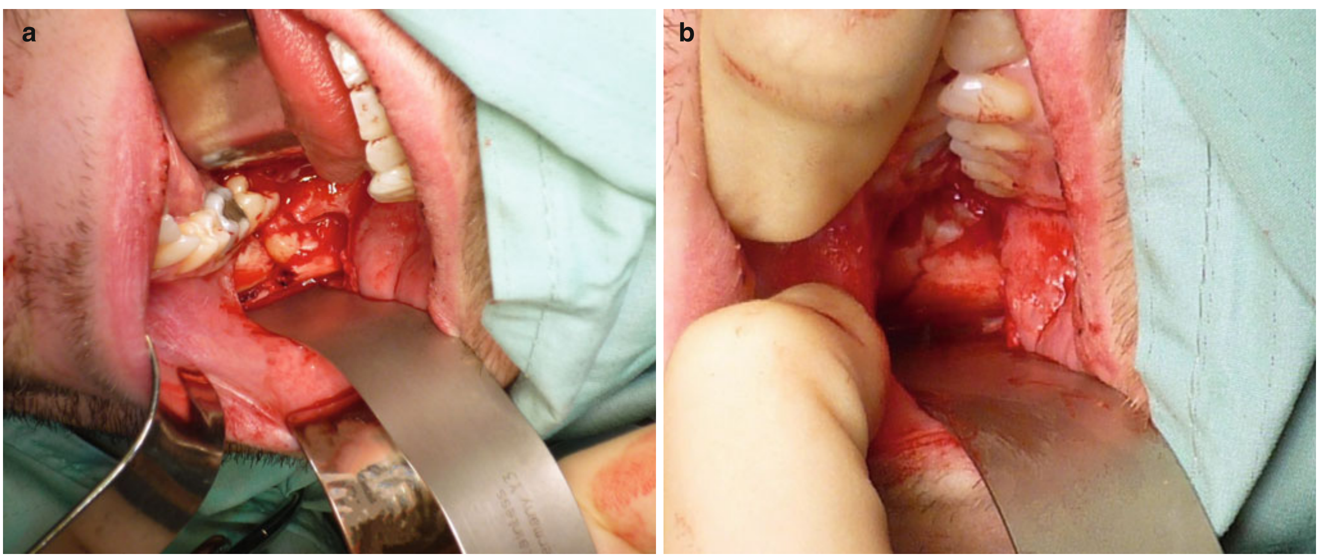

Fig. 6.35 The fracture could be easily reduced (**a**). It was decided to leave the third molar in situ (**b**). Removal would have required bone loss

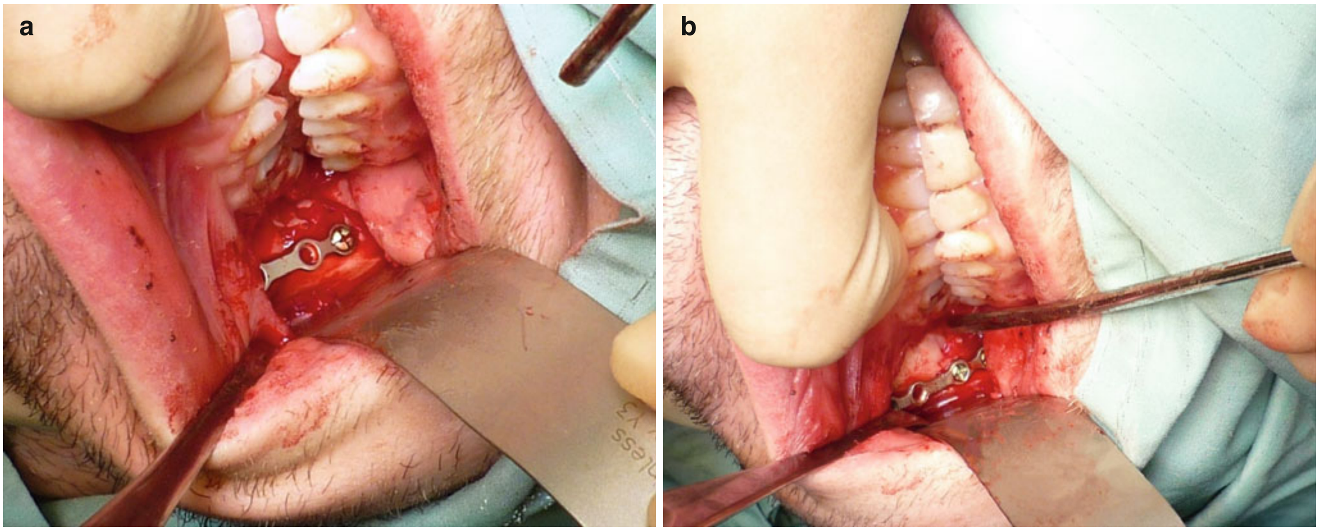

Fig. 6.36 The plate was secured to the posterior fragment (**a**), approximating to Champy's line (**b**)

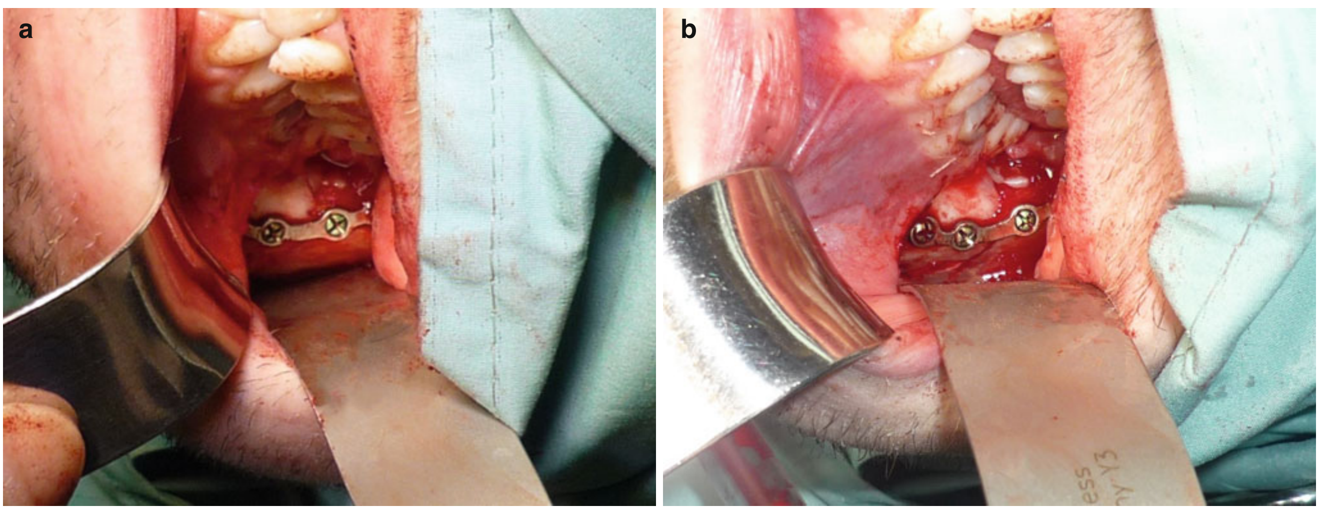

Fig. 6.37 With the occlusion firmly held in place and the fracture reduced (**a**), the remaining screws were placed (**b**)

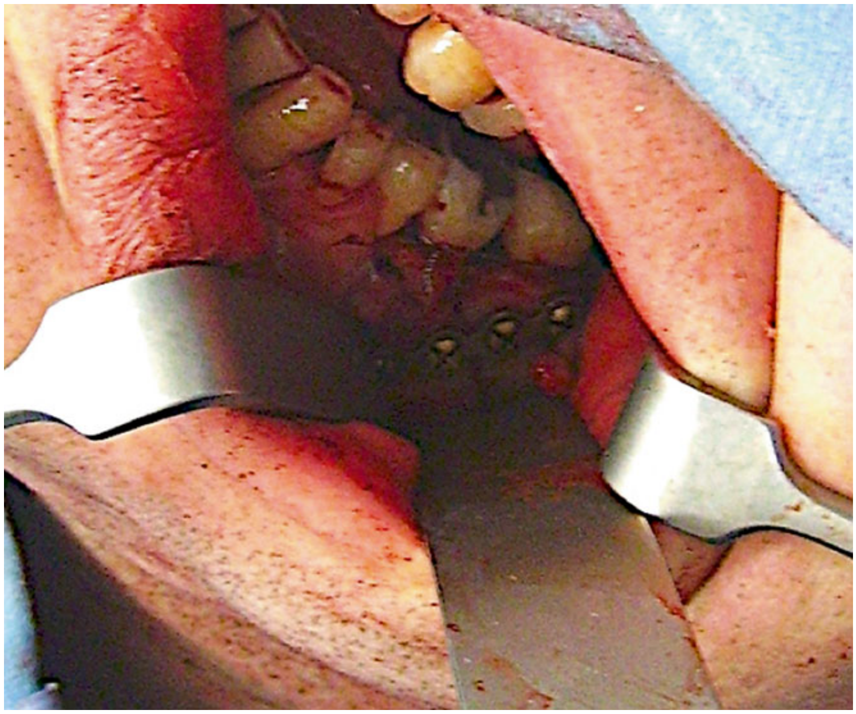

Fig. 6.38 In this case, a slightly more lateral plate was used. This was still placed transorally

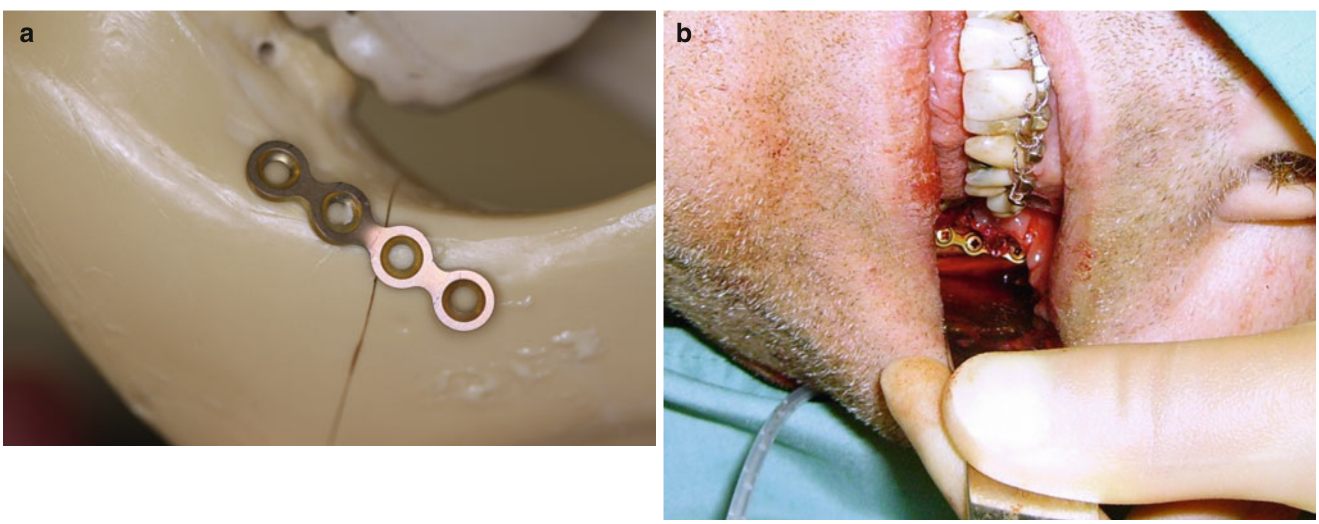

Fig. 6.39 Posterior plates secured along Champy's line (**a**) are easy to place through the mouth (**b**). But the plate is relatively superficial and can become exposed

Case 2

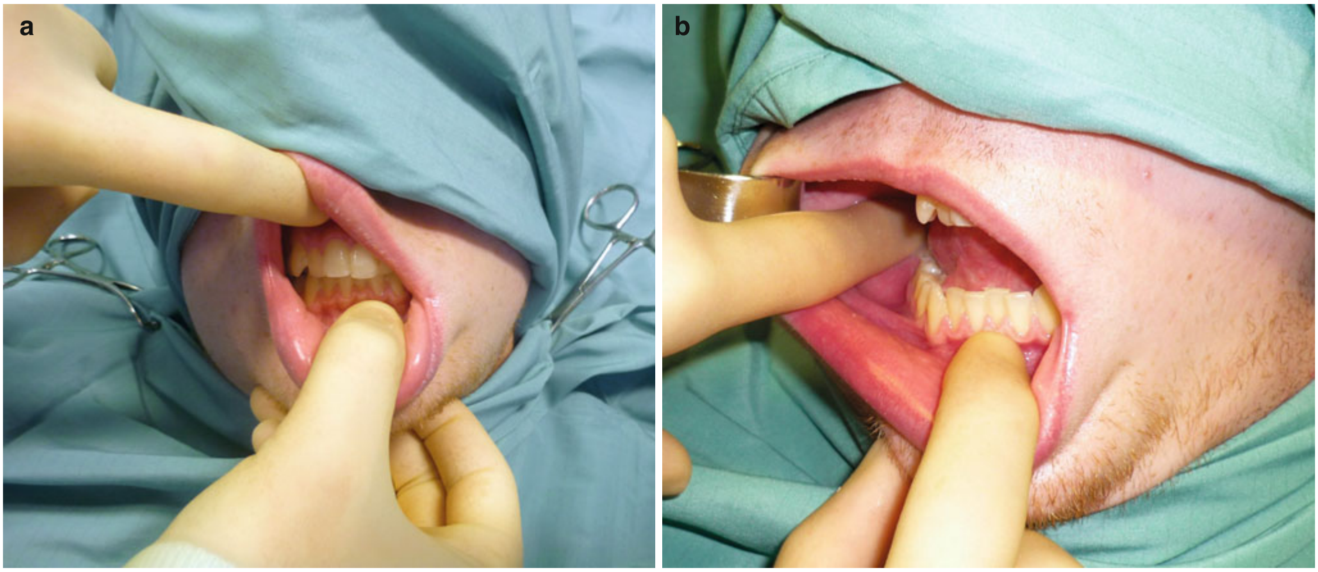

Fig. 6.40 (**a**, **b**) The fracture is examined initially and the occlusion assessed

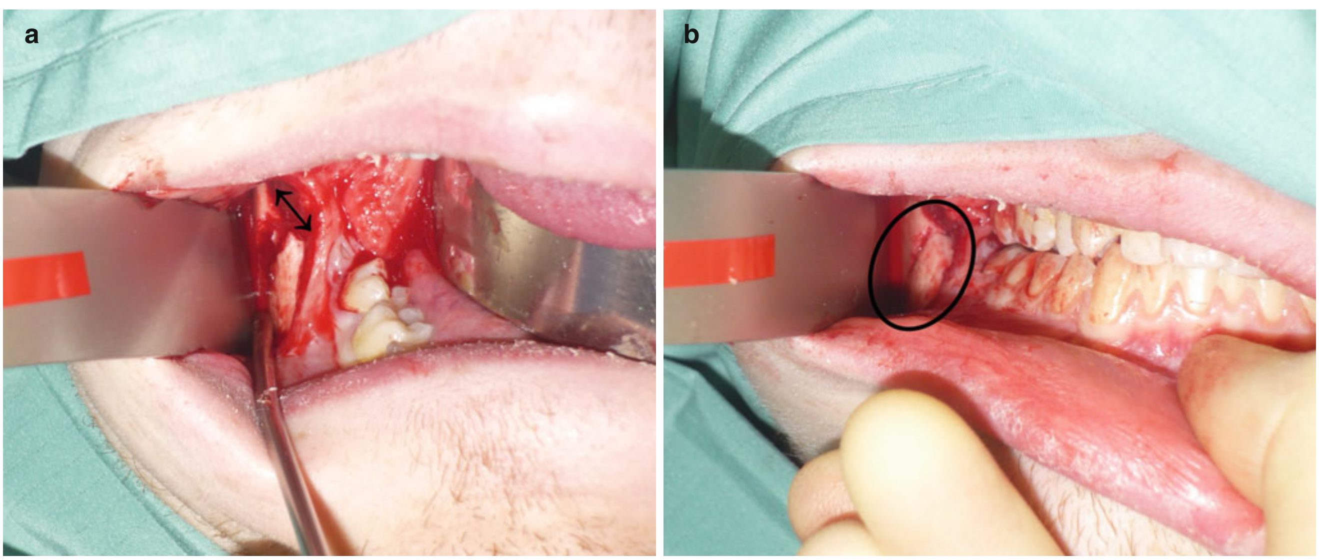

Fig. 6.41 (**a**, **b**) Following exposure similar to case 1, the fracture can be easily reduced using the retractor while holding the teeth in occlusion

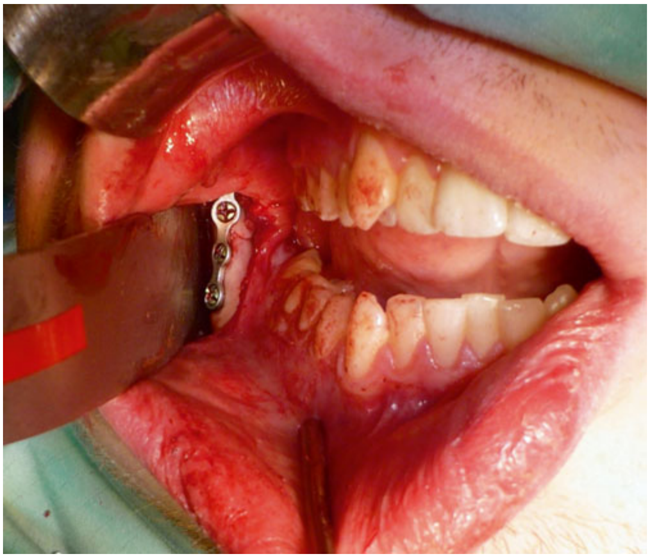

Fig. 6.42 This fracture was slightly more posterior than case 1. Consequently the plate required a “propeller” twist to get a good fit

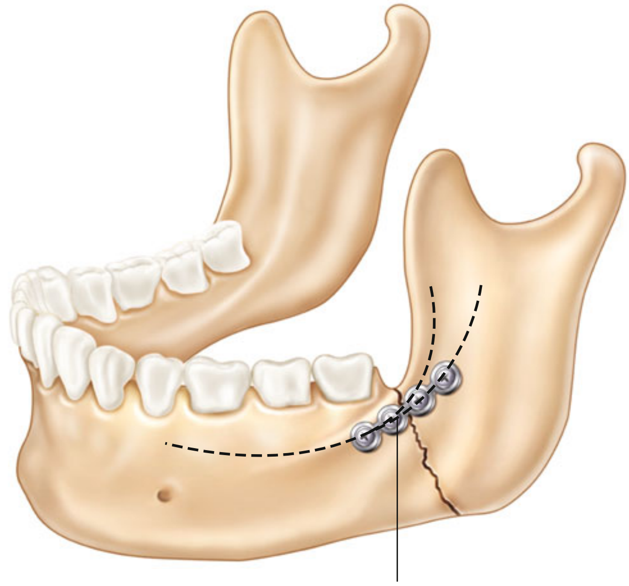

Fig. 6.44 Champy’s lines

Fig. 6.43 Percutaneous (transbuccal) fixation allows greater freedom in placing plates

Fig. 6.45 Minimally displaced angle fracture secured with a single plate along Champy’s line

Percutaneous Trocar Repair

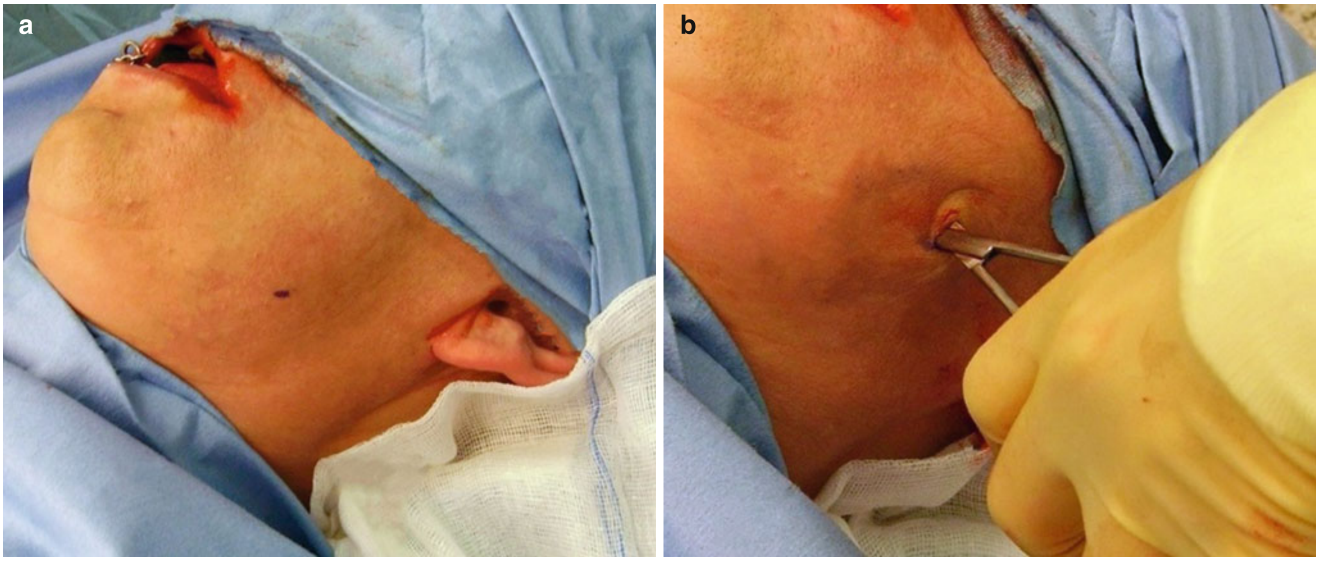

Fig. 6.46 Following a stab incision (**a**), a curved clip can be used to blunt dissect to bone (**b**). Some surgeons proceed directly to the trocar without use of the clip

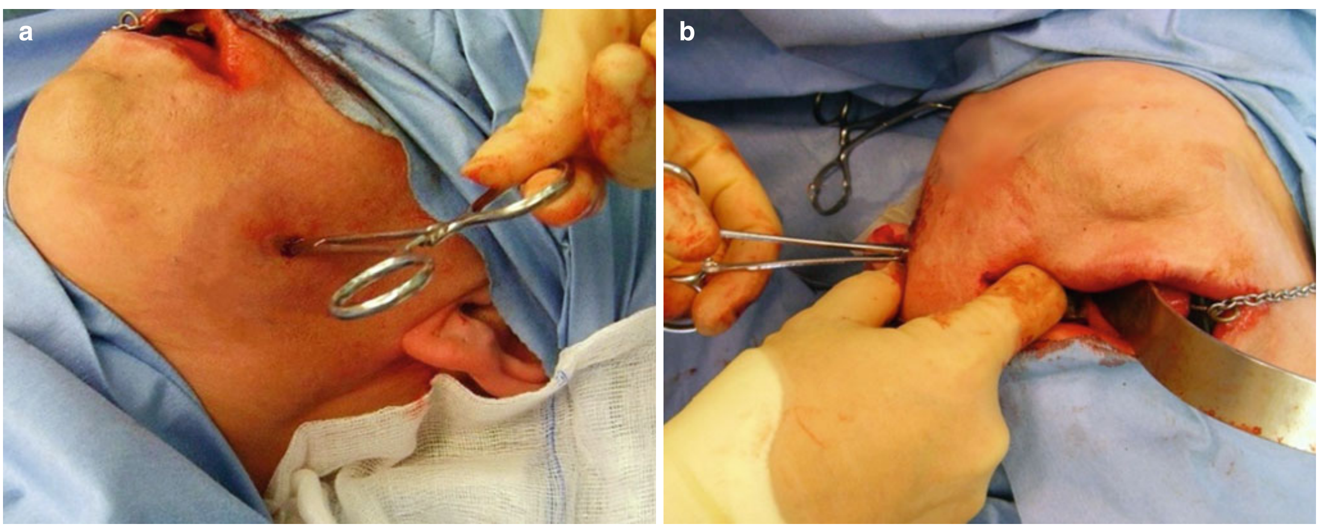

Fig. 6.47 The clip is passed through the buccal mucosa and onto the exposed fracture (**a**, **b**)

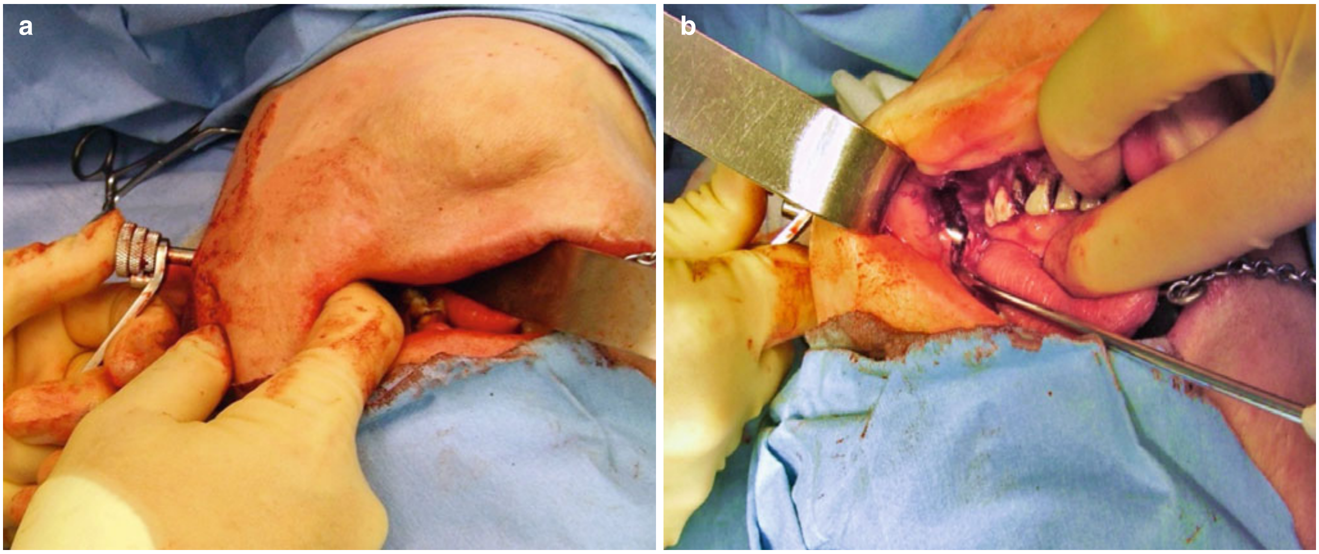

Fig. 6.48 The trocar is placed (**a**). This is then replaced by the drill guide (**b**)

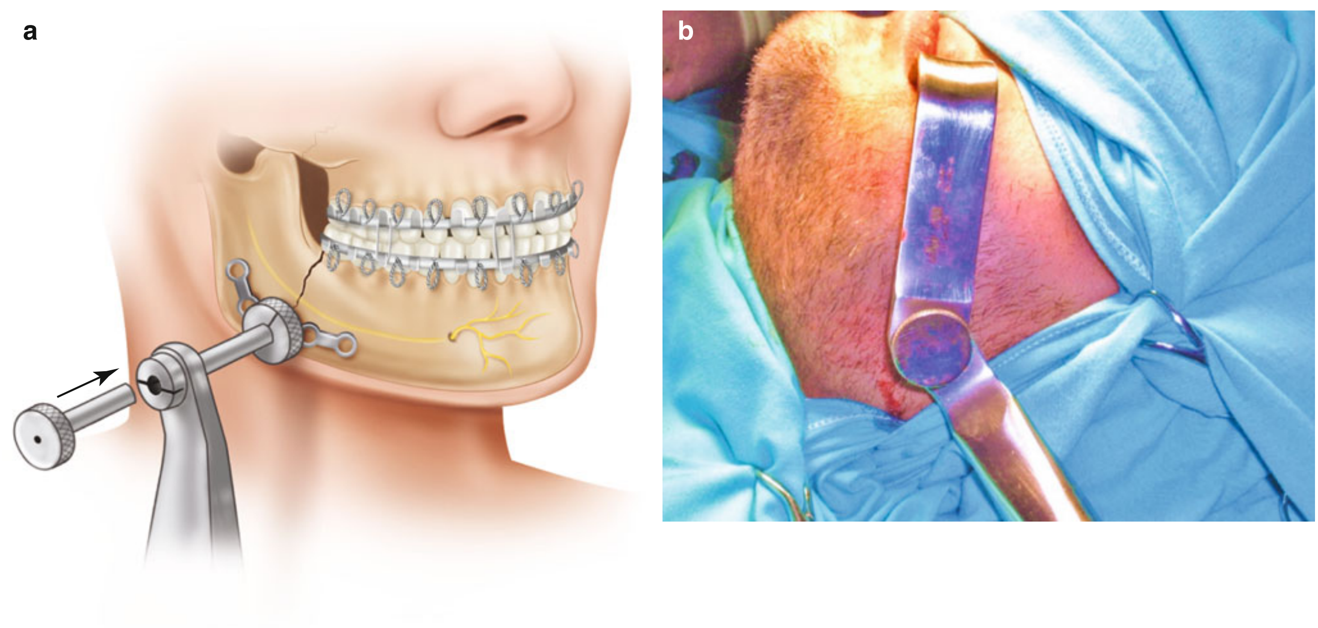

Fig. 6.49 Transbuccal drills come in various designs. (**a**, **b**) Cheek retraction is important to allow good visualisation while drilling

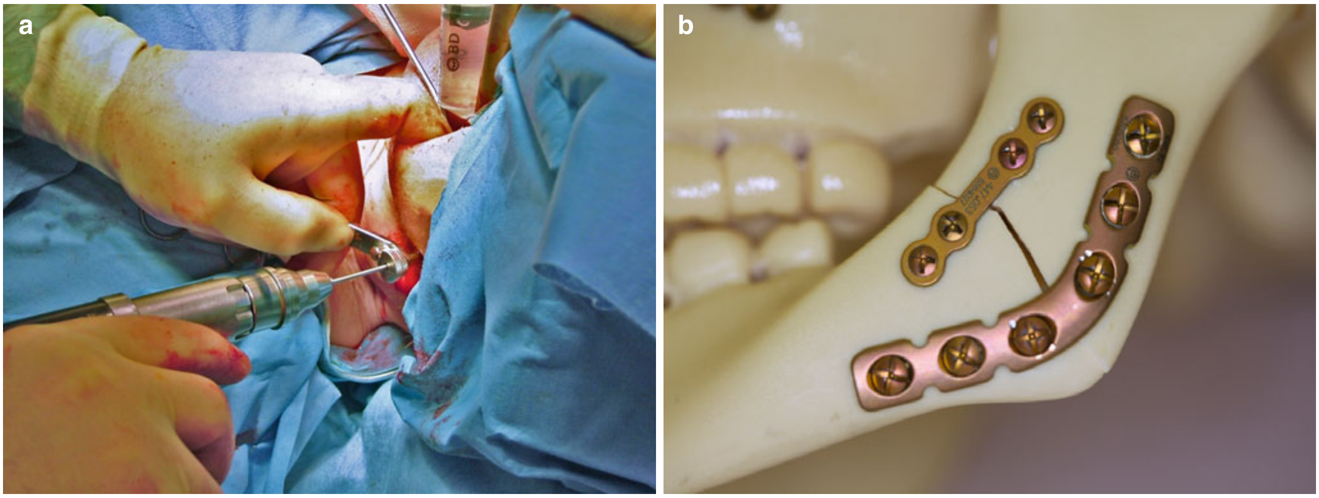

Fig. 6.50 Following insertion of the drill guide (**a**), the plate (**b**) is held in place and secured. This technique provides much greater freedom in plate placement

6.5.2.2 Transcutaneous (Extraoral) Repair

Most mandibular fractures can usually be repaired through a transoral incision. However, on occasion an extraoral approach is required. This is usually undertaken whenever precise anatomical reduction or reconstruction of the lower border is required, but is not possible through the mouth. Situations where an extraoral approach may be required include:

- Comminuted fractures
- Severely atrophic mandibles
- When bone grafting of a continuity defect is required or
- When rigid fixation is needed, using bulkier plates

Access to the lower border of the anterior mandible is relatively straightforward. However, care is required as the marginal mandibular branch of the facial nerve is commonly encountered (see Fig. 6.51).

Anterior Approach

For midline anterior fractures the risk of injury to the facial nerve is relatively low. An incision is placed in a suitable skin crease in the submental region, alongside the lower border. Dissection then proceeds through the underlying platysma muscle, down to the periosteum, which is then incised and elevated. With careful undermining of the soft tissues, surprisingly good access is possible through a relatively small skin incision (see Figs. 6.52–6.59).

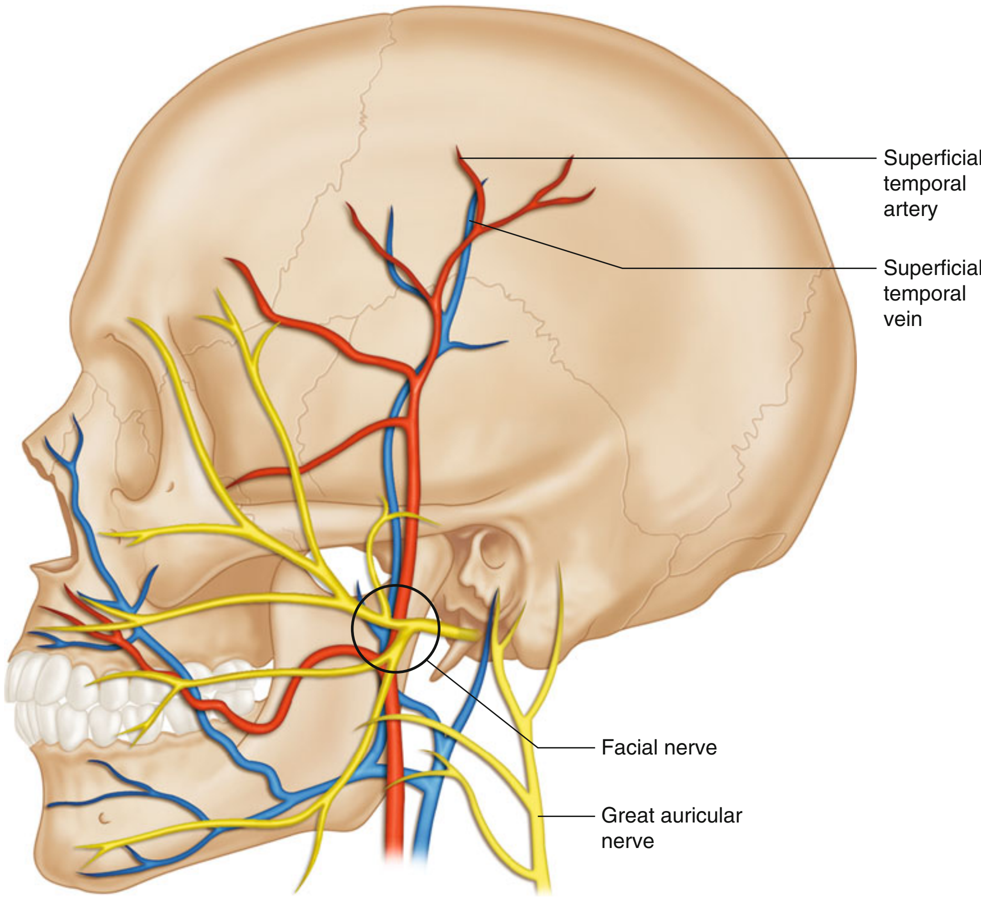

Fig. 6.51 The mandibular branch of the facial nerve (marginal mandibular) crosses the lower border of the mandible. It runs a variable course and is therefore at risk when exposing the lower border through the skin

Case 1

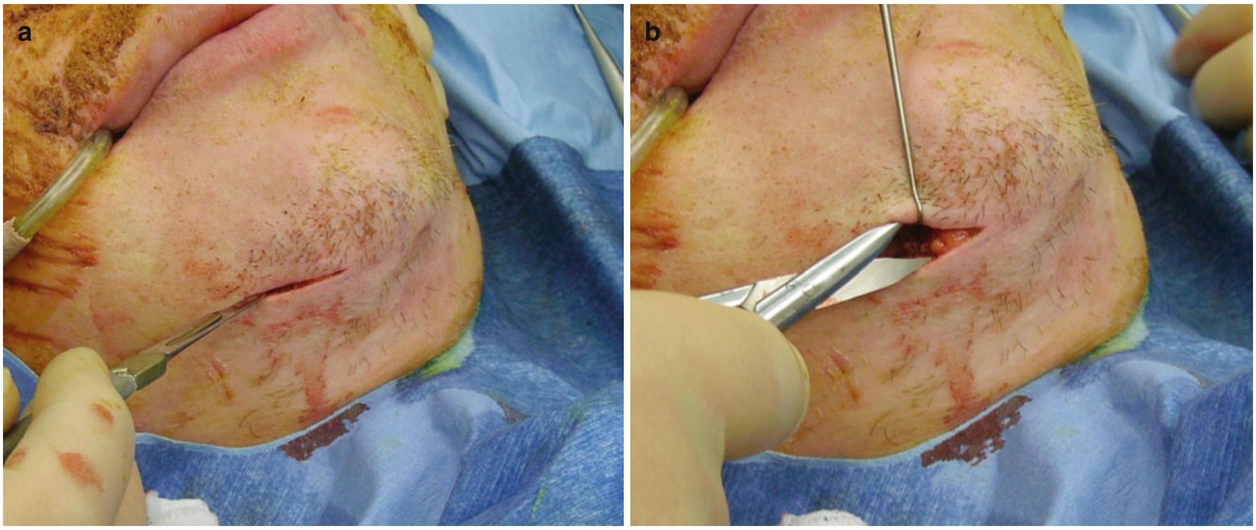

Fig. 6.52 The incision is placed in a suitable skin crease (**a**), followed by blunt dissection (**b**)

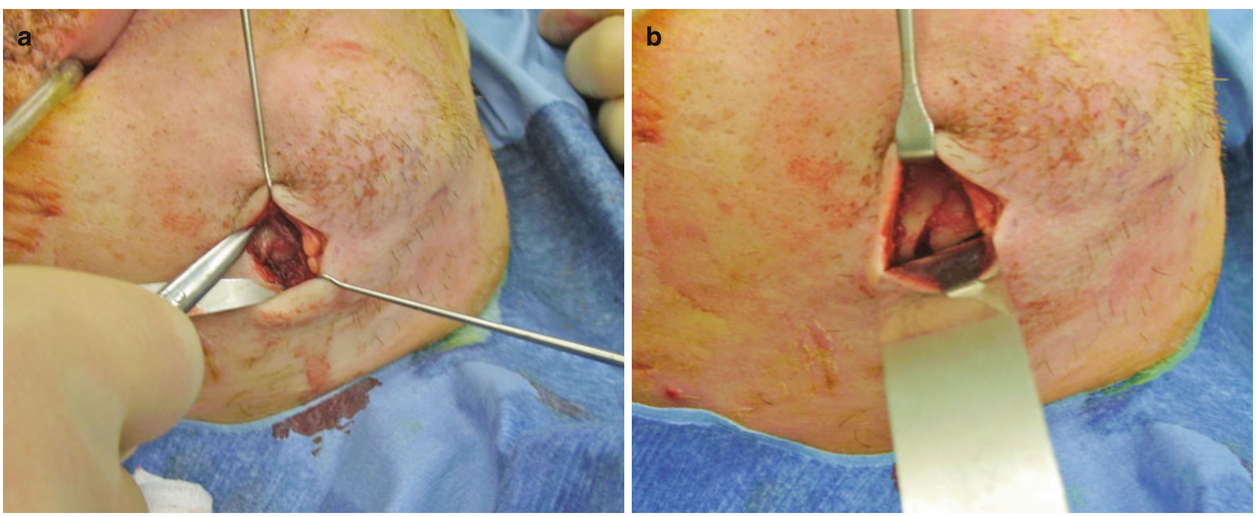

Fig. 6.53 The fracture is usually found quickly (**a**). The periosteum is then incised and elevated (**b**)

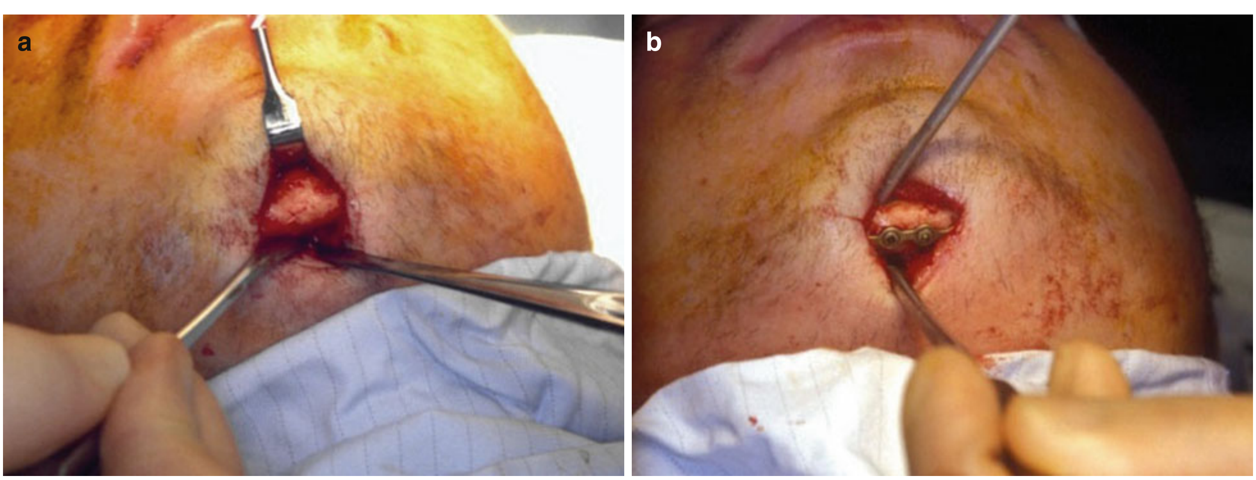

Fig. 6.54 In this example, the fracture is easily reduced and fixed along the lower border (**a**, **b**)

Case 2

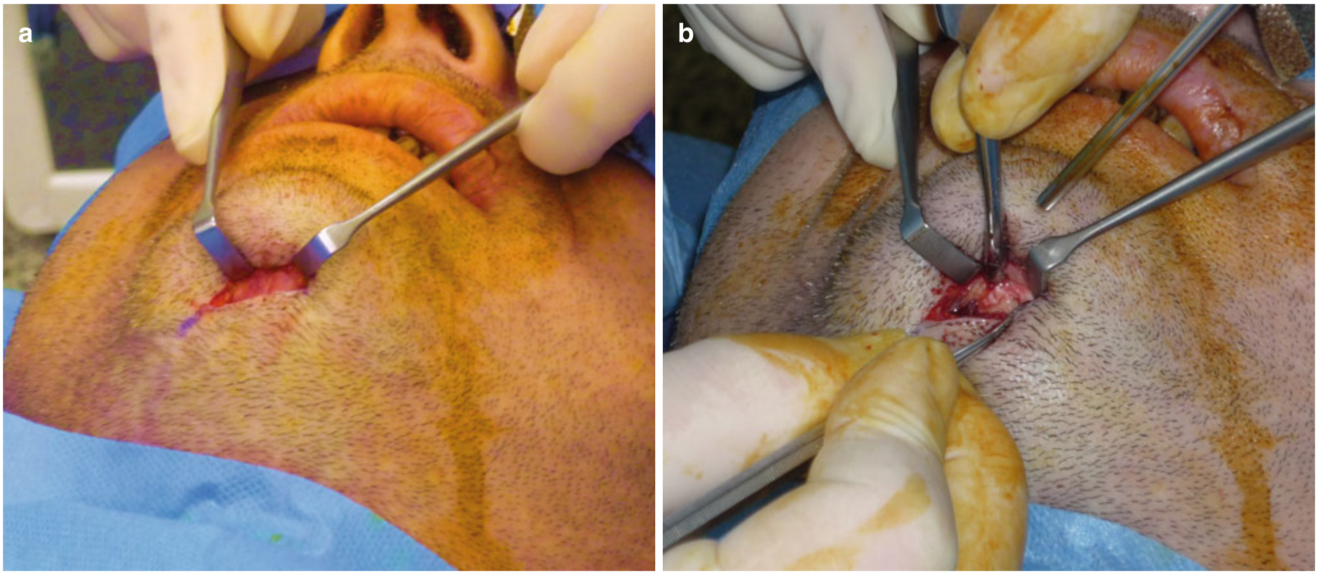

Fig. 6.55 Initial dissection as for case 1 (**a**, **b**)

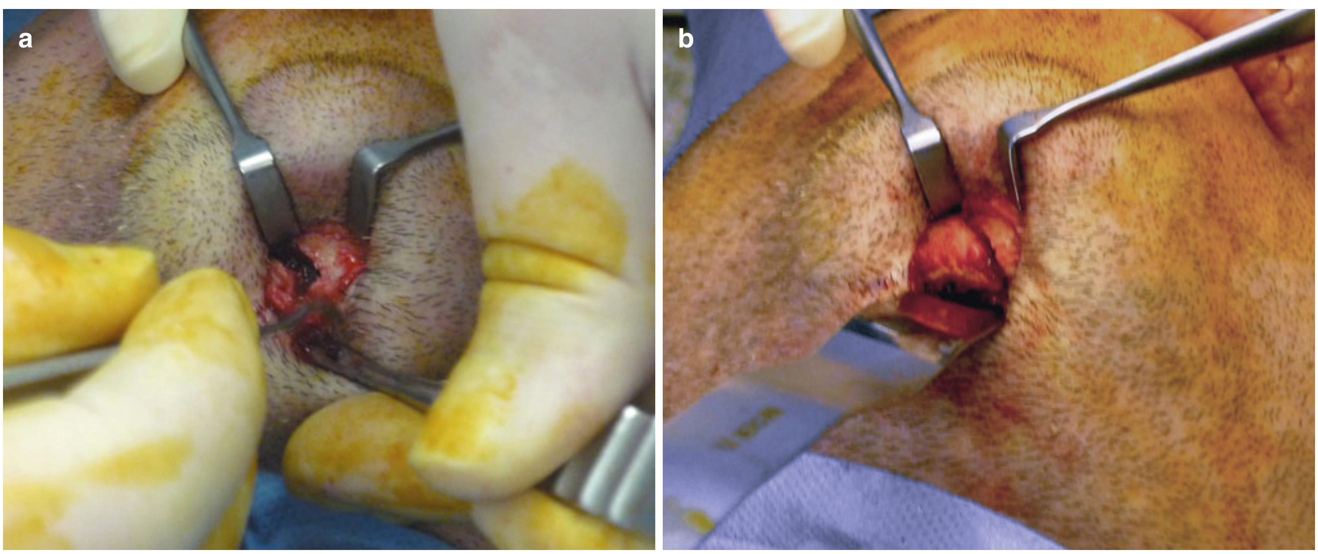

Fig. 6.56 The fracture is exposed (**a**, **b**)

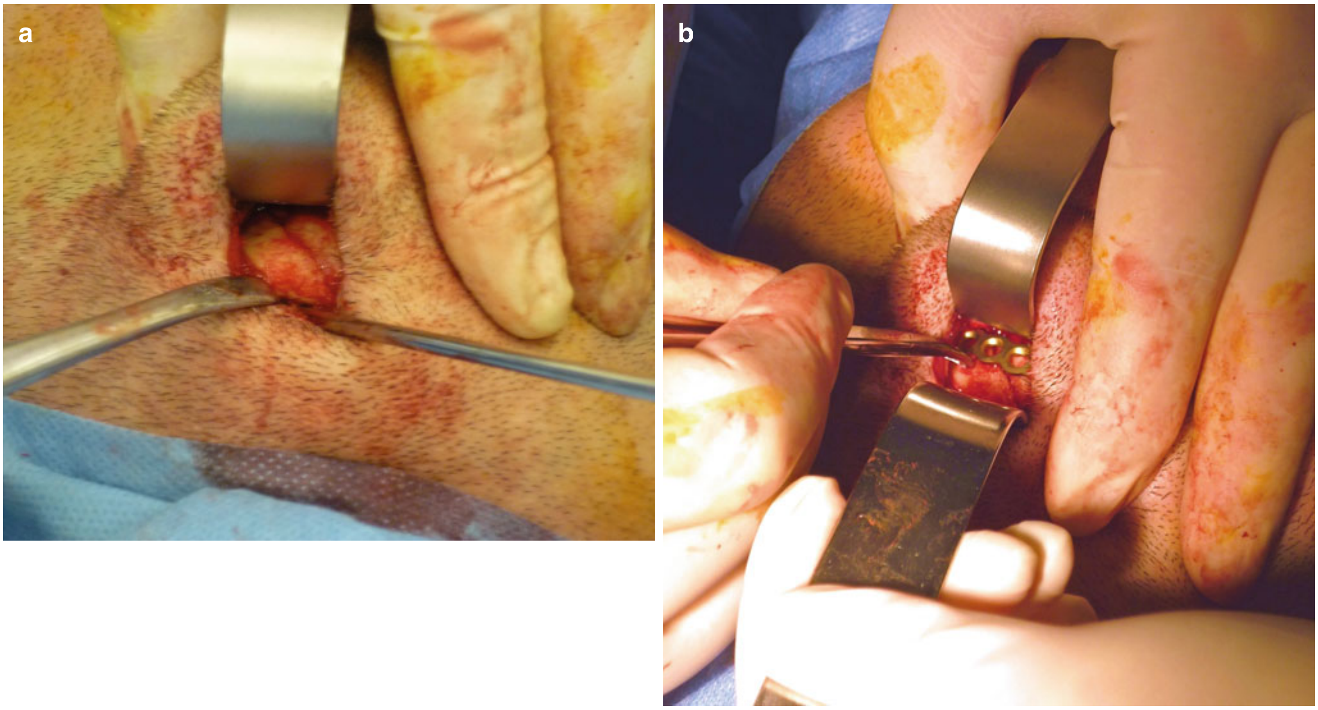

Fig. 6.57 Following reduction, the plate is adapted to the lower border (**a**). A thicker 2.3-mm plate has been chosen here (**b**)

Fig. 6.58 The holes are drilled using a drill guide (required for this particular plate) (**a**, **b**)

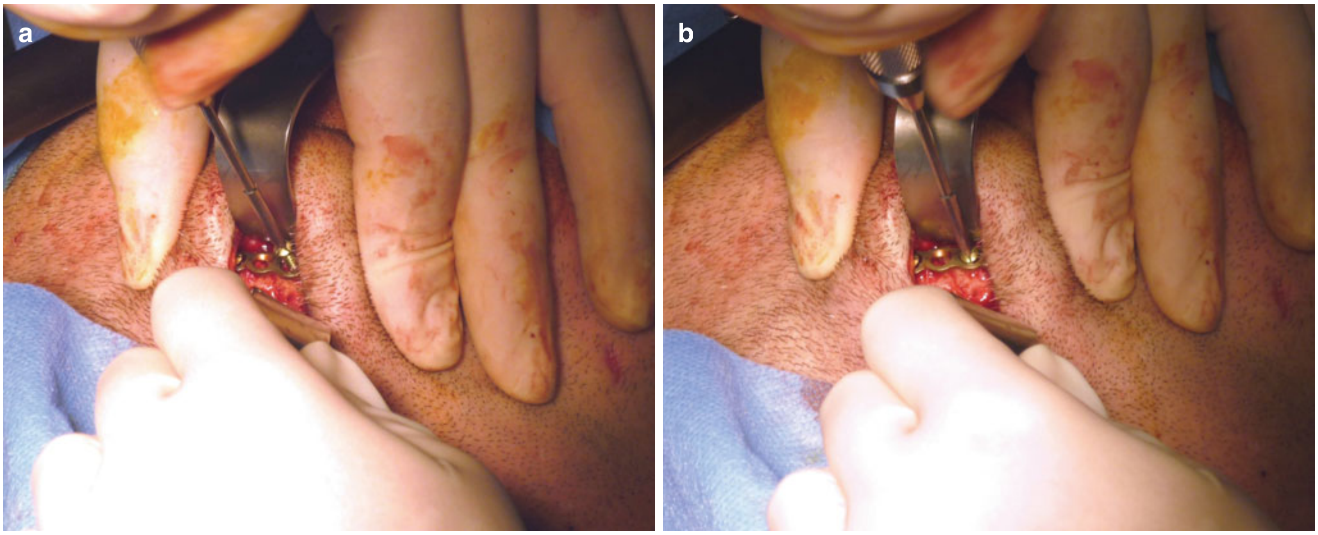

Fig. 6.59 Screw placement. The teeth are manually held in occlusion. The lower border is much thicker than the rest of the bone. This is a good site for fixation. Strong plates can be firmly secured here, making for a much more rigid repair (**a**, **b**)

Posterior Approach

With posterior approaches to the lower border, the likelihood of nerve injury increases and greater care is required. This approach is very similar to that when removing a submandibular gland (sometimes referred to as a Risdon incision). The incision is placed lower down in the neck, usually in a suitable skin crease. Traditionally it is taught that the incision must be at least "two finger-breadths" below the lower border of the mandible. However, this is often quite a low incision and is generally not necessary. It also makes access to the fracture considerably more difficult, particularly when trying to manipulate bone fragments and repair them. When such low incisions are used they often need to be extended.

Alternatively, a slightly higher incision placed in a suitable skin crease will improve access to the lower border and with care does not put the nerve at great risk. It is not the skin incision that damages the nerve, but the dissection that proceeds afterwards that does (see Figs. 6.60, 6.61 and 6.62).

Case 1

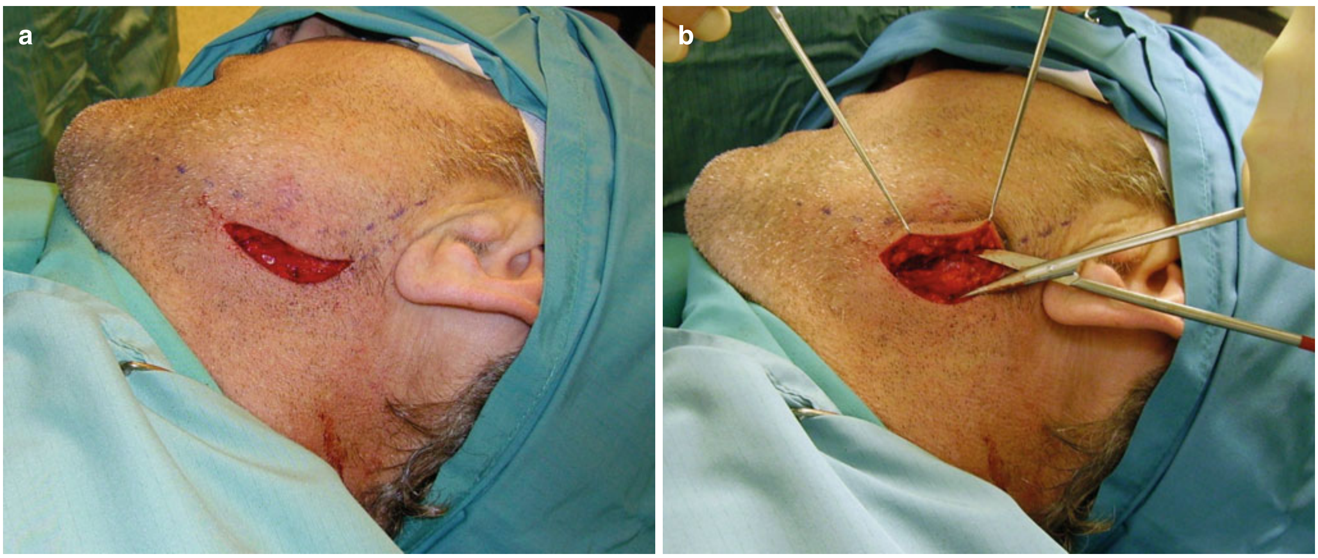

Fig. 6.60 A full-thickness skin incision (**a**) is followed by careful dissection towards the lower border (**b**)

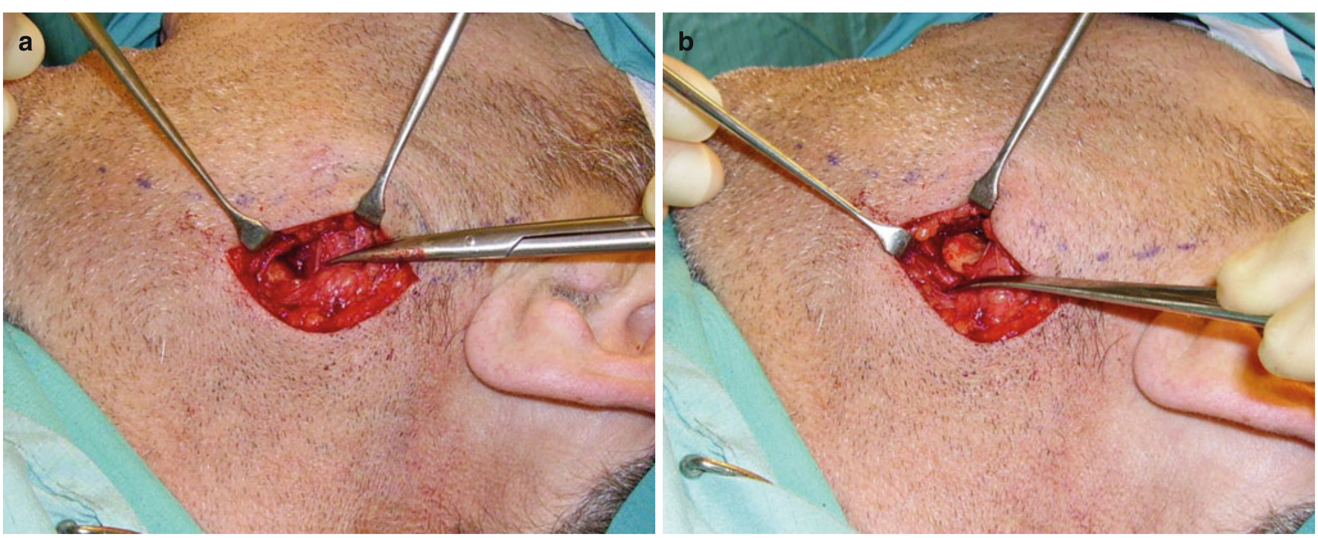

Fig. 6.61 The mandibular branch is frequently encountered. This can be gently retracted prior to periosteal incision. The fracture is then exposed and reduced (**a**, **b**)

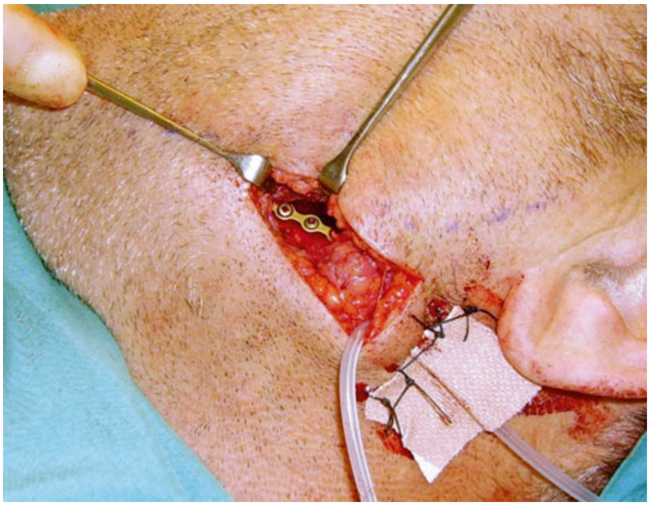

Fig. 6.62 Lower border fixation

Following skin incision, the underlying superficial fascia is gently separated with tenotomy scissors to expose the underlying platysma muscle. The platysma muscle is then carefully incised and retracted. It is at this stage that the marginal mandibular nerve may be encountered as shown. (Depending upon the precise position of the incision, the facial artery and vein may also be encountered. These can either be retracted or divided, depending upon the access required). Once the platysma has been fully incised both the upper edge and the adjacent nerve can be gently retracted upwards. The lower border of the mandible is then usually easily palpable through deep fascia and periosteum. These tissues can then be incised and elevated to expose the bone (see Figs. 6.63–6.68).

Following fracture repair, the wounds are closed in layers. If a significant amount of exposure has been required it may

Case 2

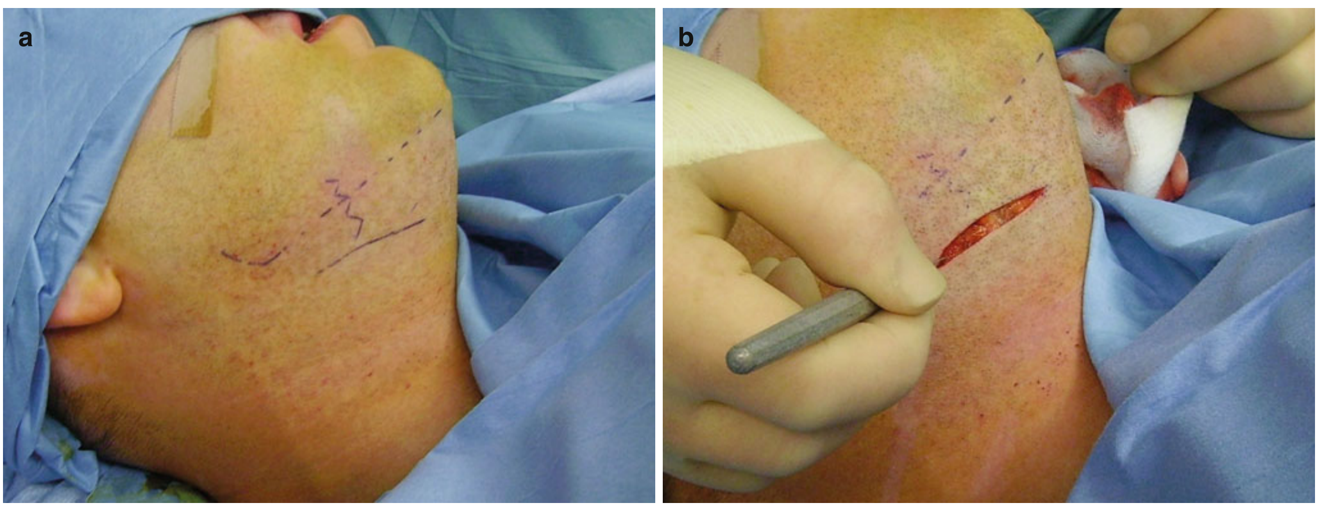

Fig. 6.63 Skin incision (**a**, **b**)

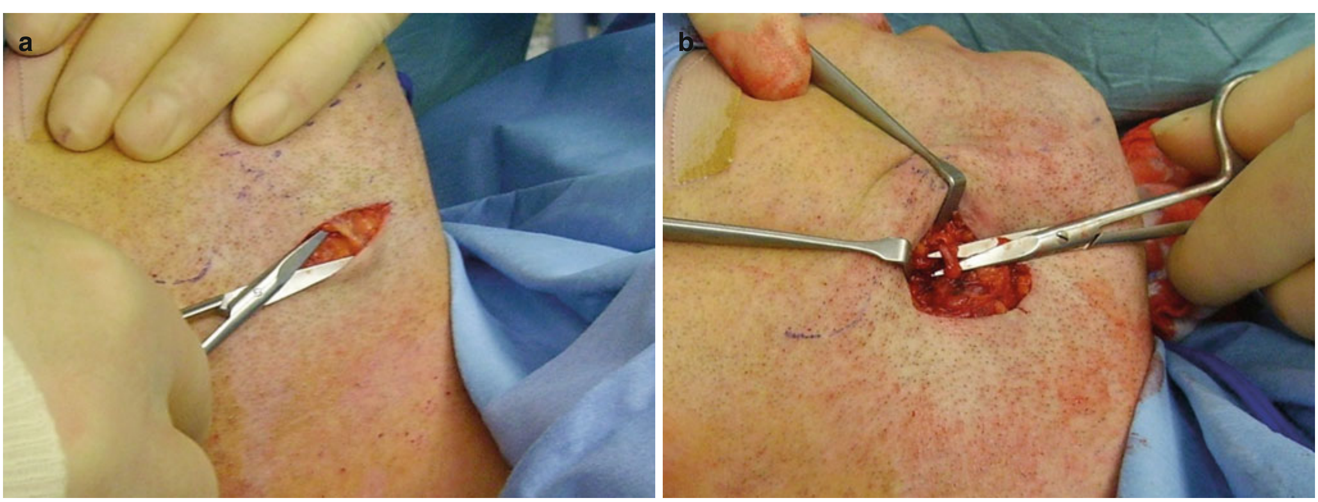

Fig. 6.64 Blunt dissection through the platysma (**a**). Depending on the precise location, the facial artery and vein may need to be ligated and divided to facilitate exposure (**b**)

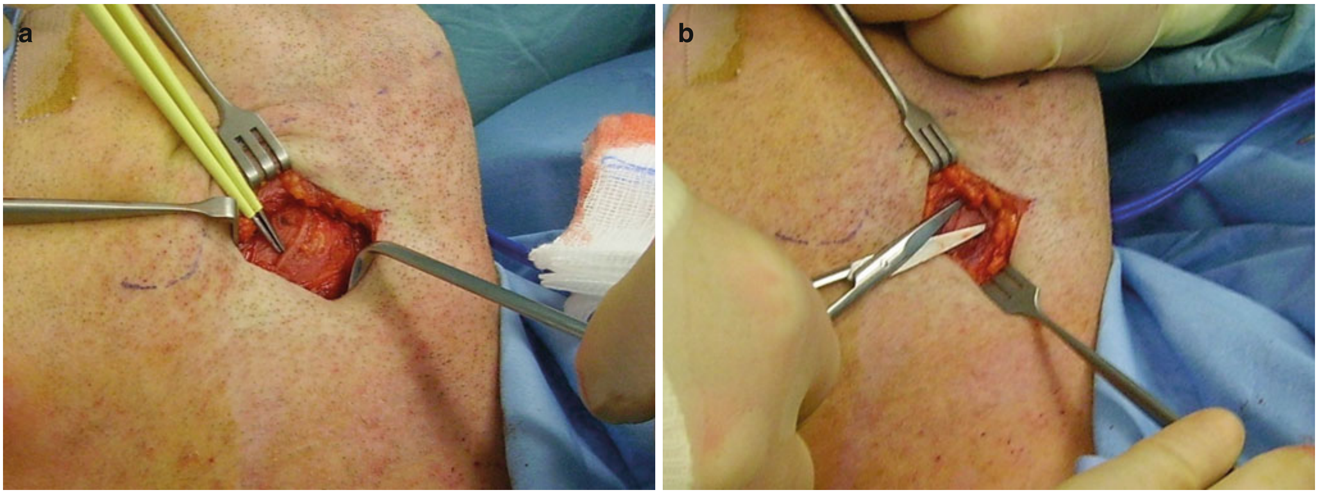

Fig. 6.65 The mandibular branch is identified (**a**) and protected (**b**)

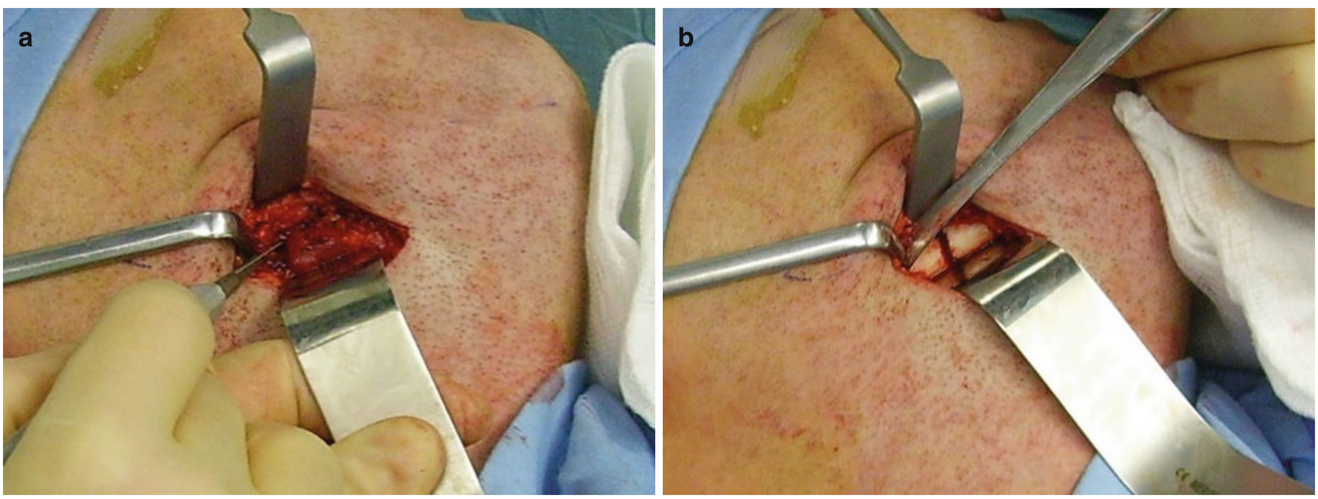

Fig. 6.66 The periosteum is incised (**a**) and elevated (**b**)

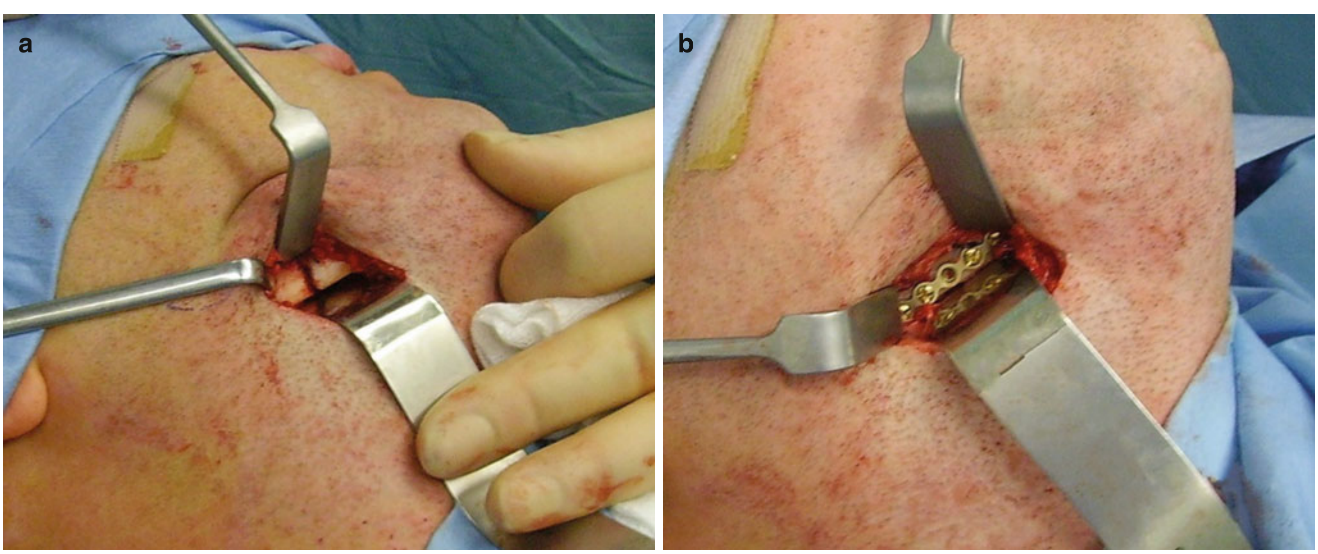

Fig. 6.67 Excellent exposure for reduction and fixation (**a**, **b**)

Fig. 6.68 The nerve is frequently encountered with this approach, as seen in this example

be wise to place a small suction drain to prevent haematoma formation postoperatively.

Extended Access

This may be required in comminuted fractures involving much of the lower border. By their very nature, these sorts of injuries will often be very swollen and a surgical airway may be required. A long skin incision approximately parallel to the lower border is deepened by blunt dissection using the combined steps of the anterior and posterior approaches just described. Exactly where the skin incision is placed depends on a number of factors, such as how swollen the patient is, existing lacerations, and suitable skin creases. In the case shown, the incision has been staggered, to minimise unfavourable contraction of the scar later (see Figs. 6.69 and 6.70).

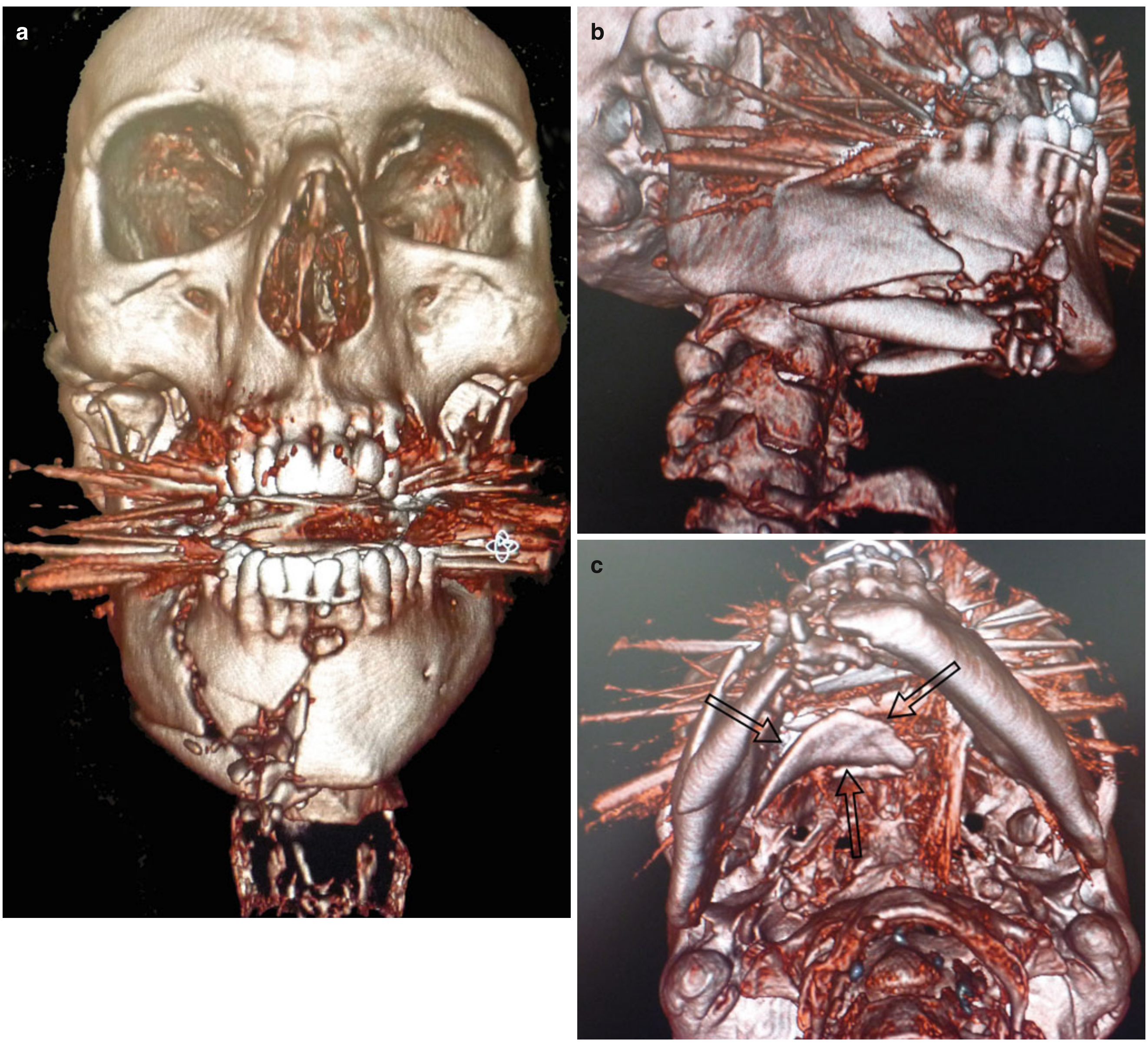

Fig. 6.69 Comminuted mandibular fracture following a kick from a horse (**a–c**)

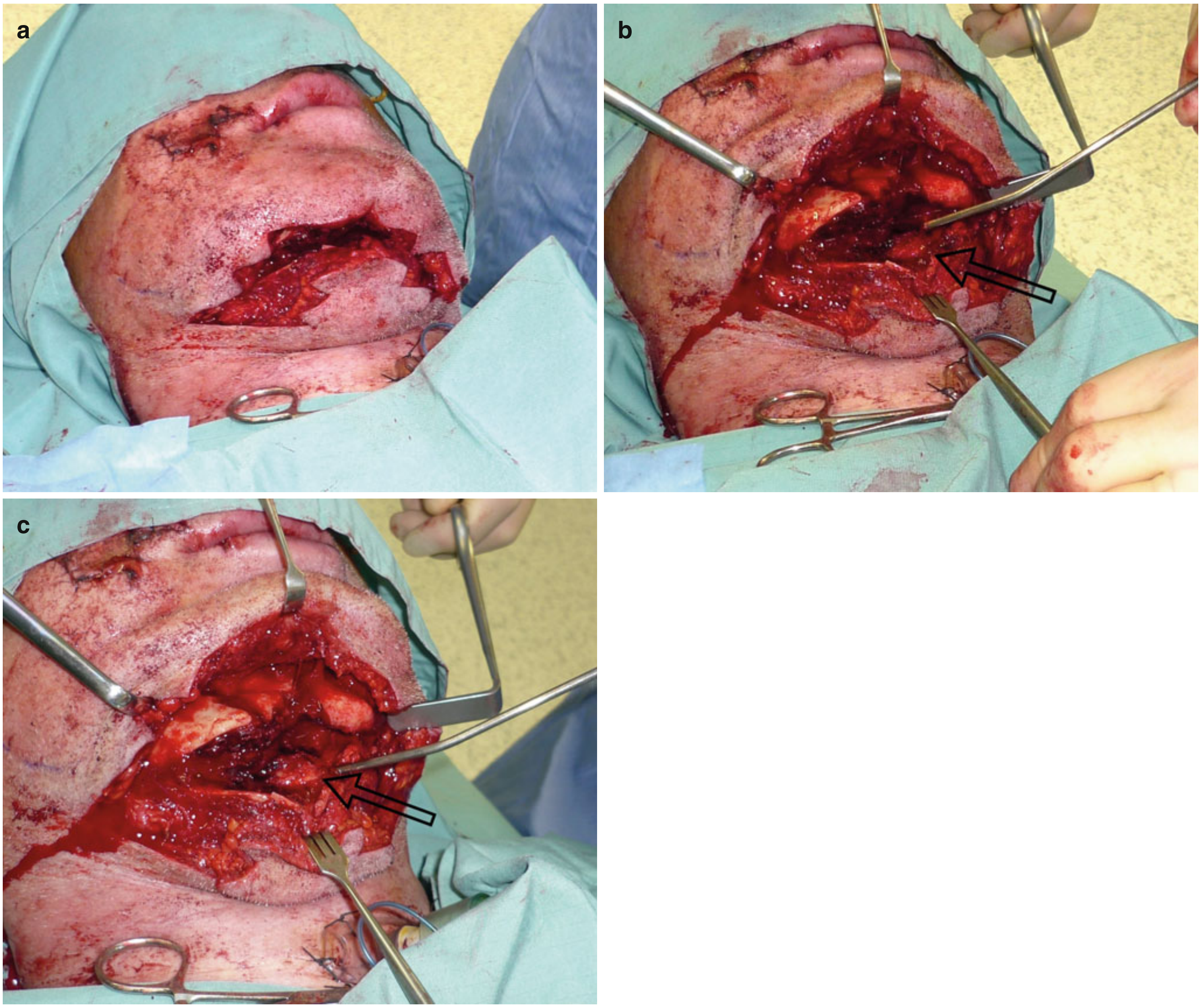

Fig. 6.70 This injury required extensive access to enable rigid fixation of the lower mandibular border and retrieval of the grossly displaced lingual plate. In such cases, conventional "load sharing" osteosynthesis is likely to fail (**a**–**c**)

6.5.3 Where Exactly Do the Plates Go?

It is generally accepted that in the anterior mandible (i.e., between the mental foramina), two plates are required. These resist the torsional forces produced by the attached muscles (mylohyoid, geniohyoid). Ideally the plates need to be separated as far as possible. Two plates next to each other is therefore not the best arrangement. If possible the upper plate should be placed approximately 5 mm below the apices of the teeth (to minimise risks to the apical blood supply). The lower plate should be placed as low as possible for maximal stability, ideally along the lower border. This would be regarded by many as the gold standard (see Fig. 6.71).

In reality, two remote points of fixation are needed, rather than two plates. On this basis, it may be possible to successfully manage some fractures using a single plate as one point of fixation and the lower teeth as the other (by splinting the

Fig. 6.71 Anterior fractures require two points of fixation, usually provided by two plates

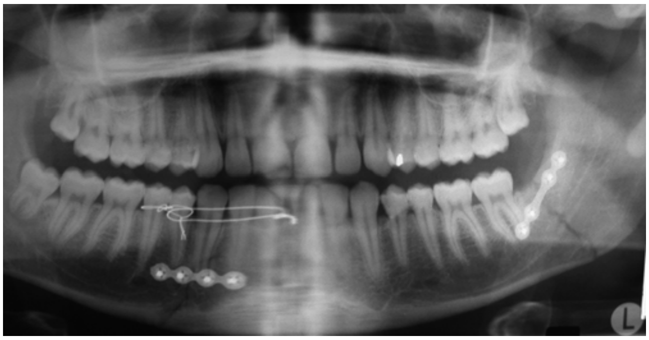

Fig. 6.72 Two-point fixation has still been achieved at the parasymphysis. By firmly ligating the lower teeth, the dental roots act like a miniature external fixator. Case selection is very important. This technique does not work in every case. Note the single plate at angle fracture, following Champy's line

teeth either side of the fracture with a short arch bar or circumdental wire). In essence the teeth and arch bar act like a miniature external fixator (see Fig. 6.72).

This technique works well with selected simple fractures and may be useful when the mental nerve is thought to be at significant risk during repair. By limiting repair to a single plate, this avoids a much more extensive dissection (to gain sufficient exposure of the lower border) and stretching of the mental nerve. It does, however, depend on healthy lower teeth and supporting structures, and good interfragmentary reduction. Case selection is therefore very important. This should not be used as a "short cut" in treatment. If the teeth are damaged, diseased, or loose, it is not recommended to try this. In selected cases of incomplete anterior fractures (where the lower mandibular border has not been completely split, but the upper end of the fracture is separated), a small arch bar by itself can often suffice to close and support the fracture. IMF is usually not required (see Fig. 6.73).

These techniques are perhaps controversial and are only of use in selected cases, where there has been incomplete splitting or minimal separation of the bones and good interlocking of the fragments. In all other cases, two or more plates are usually required.

Posteriorly, it is generally accepted that only one plate is required in most simple fractures. However (as noted previously), some surgeons have looked at the role of transbuccal placement of two miniplates in the repair of angle fractures. This is reported to enhance stability, yet avoid the external incisions required for larger plates. Different plate configurations have been reported, all with good success rates. The upper plate is often positioned above the ID nerve, but more laterally, while the second plate is placed along the lower border (see Fig. 6.74).

If only one plate is used, this is traditionally taught to be positioned high, following Champy's line along the external oblique ridge (see Fig. 6.75). This may require adapting a "propeller" twist in the plate, which can sometimes be difficult. Such high fixation may also result in the plate being placed

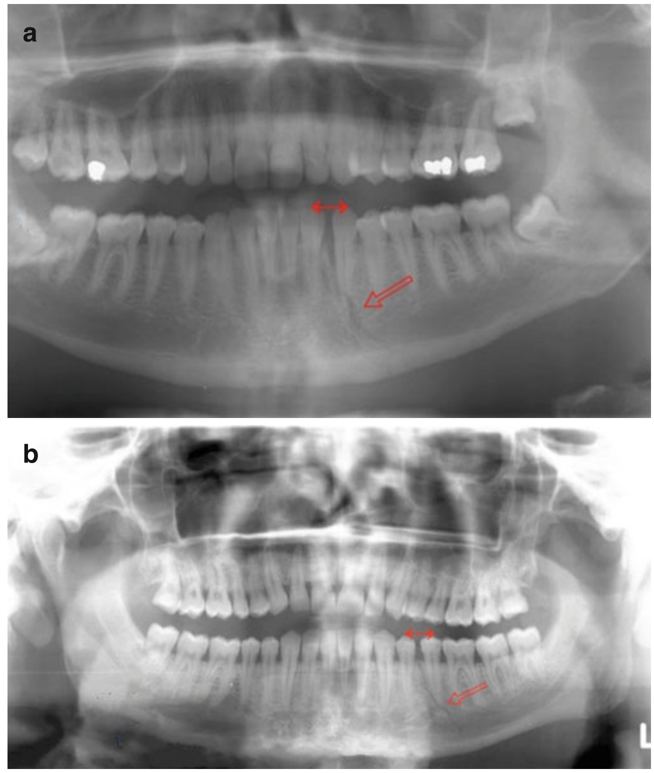

Fig. 6.73 Not all fractures need repair. Incomplete splits with intact lower borders can be managed by ligating or splinting the lower teeth with an arch bar (**a**, **b**). Close follow-up and good patient cooperation is essential

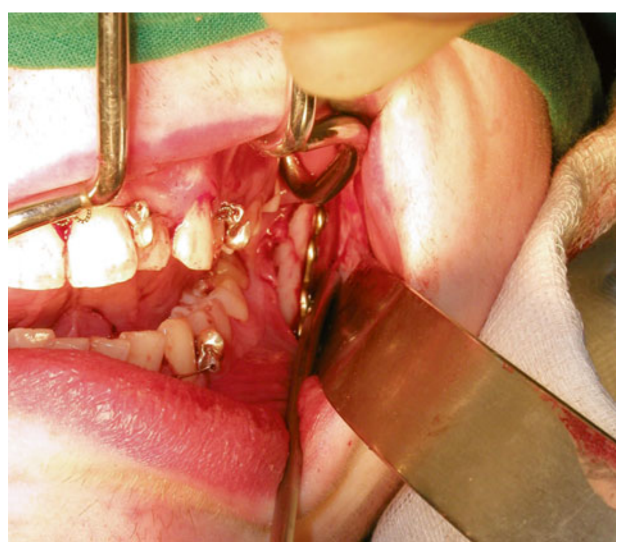

Fig. 6.74 Lateral placement of a posterior plate is reported to have fewer complications. However, it does necessitate a percutaneous trocar

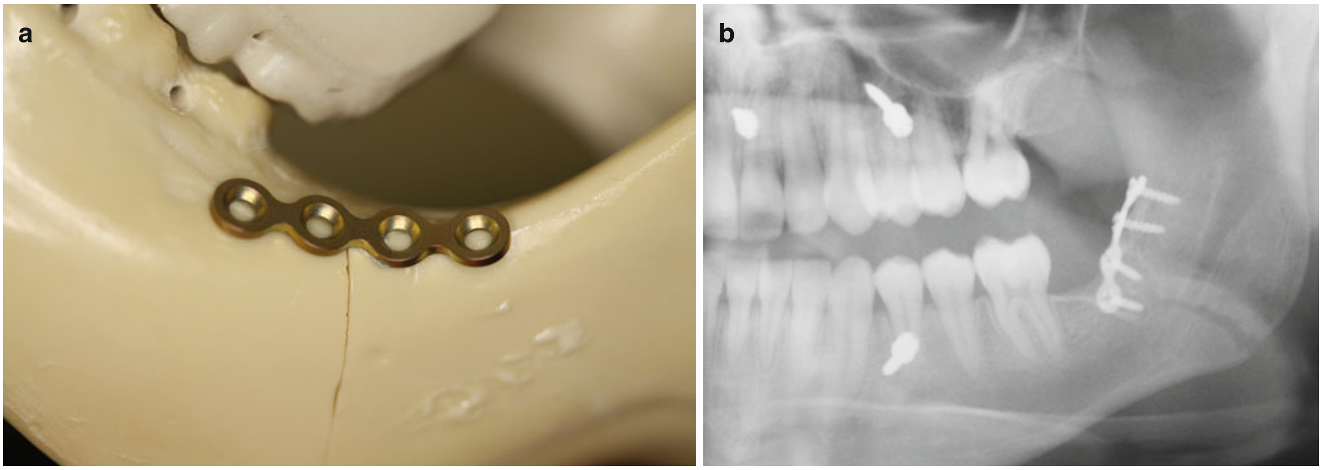

Fig. 6.75 (**a**, **b**) Upper border plate (Champy's line)

directly under the mucosal incision, with an increased risk of exposure. For these reasons, some surgeons prefer the "transbuccal" approach, allowing slightly more lateral placement.

At present, it is not entirely clear whether one or two plates is best in the treatment of simple posterior fractures. With comminuted fractures, stability is considerably less, as there are more "pieces" to put together. Consequently several plates are often required.

6.5.4 External Fixation

This technique can provide rapid fixation of extensive injuries with relatively minimal soft tissue disruption. As such, its benefits lay in rapid temporary fixation (in patients requiring urgent transfer, or in those too sick to undergo lengthy surgery), or when there is extensive comminution or significant soft tissue damage. It is also effective in maintaining space and fragment orientation, in continuity defects.

External fixation is especially useful in mandibular fractures associated with high-energy transfer (such as gunshot wounds) where further, yet unpredictable tissue necrosis is likely. The full extent of tissue necrosis can take up to several weeks to "declare itself" following initial injury. Therefore, following blast or ballistic injuries, external fixation may initially be used to buy some time, allowing devitalised tissue to become apparent, while at the same time maintaining fragment position.

External fixation is essentially a "blind" and imprecise technique (in that the fractures are not directly visualised). Nevertheless, combinations of closed techniques (external fixation together with IMF) may be used in severely comminuted fractures with multiple small fragments. This avoids periosteal stripping, which can compromise vascularity and increase the risks of necrosis and infection. Head and neck radiotherapy also predisposes tissues to ischaemia and wound breakdown. External fixation therefore also has a role in the management of pathological fractures in the irradiated patient.

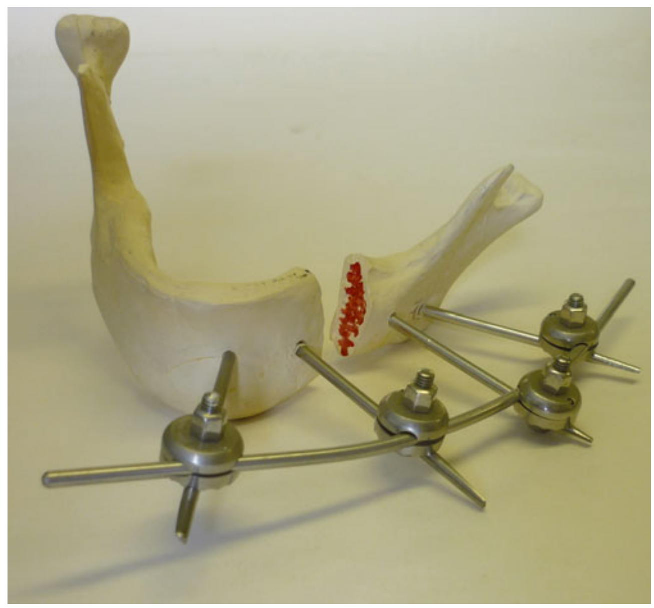

Fig. 6.76 Satisfactory external fixation requires at least two pins either side of the fracture. Many types of devises are available

In order to attain effective stability, two pins are required on either side of the fracture. Many types of devises exist, some specifically designed for the mandible, others fabricated from general external fixation kits (see Fig. 6.76). If a kit is unavailable, acrylic connecting bars can be easily fabricated with the aid of an endotracheal tube or chest drain filled with acrylic resin. Acrylic produces a lot of heat as it hardens, so care should be taken to avoid burning the patient's skin.

Unfortunately, the bulky apparatus is cumbersome for patients. Care is required not to injure themselves, a particular problem in alcoholics, children, and uncontrolled epileptics. Even modern miniature devices are still relatively obtrusive. Placement normally involves skin punctures, which can become infected and leave unsightly scars.

6.6 Management of the Tooth in the Line of the Fracture

Teeth are often involved in fractures of the mandible. The canines and third molars especially create points of weakness in the bone, hence fractures at these sites are relatively common. The concern with retained devitalised or periodontally diseased teeth, is that they may encourage infection in the fracture and ultimately nonunion or abscess formation. However, this is not likely in every case. Vital, functional, or unerupted teeth with surrounding healthy periodontal tissues can be safely left in situ in most instances. If problems develop they can be removed once the fracture has healed. Indications for removal of a tooth at the time of fracture repair are shown in Table 6.7.

Table 6.7 Indications for removal of a tooth in the line of a fracture

Root fractures (devitalised roots can act as a nidus for infection)
The tooth interferes with fracture reduction. This can occur with unerupted and underdeveloped third molars
The presence of obvious pericoronal or periodontal infection
The presence of associated pathology (such as cysts)

If a tooth needs to be removed, it is sometimes preferable to plate the fracture first, then remove the plate before elevating the tooth. Removing bone to get a tooth out should be avoided. In some instances the tooth itself helps to stabilise the fracture. Once it has been elevated, precise reduction and stabilisation of the fracture can then become tricky, particularly if bone has been removed in the process.

6.7 Condylar Fractures

Management of the fractured condyle represents a commonly debated area. It is true that several different treatment solutions may be effective in individual cases, but the trend is toward open reduction and internal fixation. Anatomical fixation and early return to function represent the fundamental treatment goals.

Management can be considered as falling into one of two groups: functional (nonsurgical) and surgical. The relative merits of each has been extensively discussed in the literature over the years. The concerns with these fractures relate mostly to the long-term results of treatment and complications, namely stability of the occlusion, joint dysfunction, ankylosis/resorption of the condyle, and abnormal growth in children. Indications and contraindications for surgical repair therefore need to be carefully considered in the decision-making process (*see* Table 6.8 and Fig. 6.77).

Table 6.8 Surgical versus nonsurgical management of the fractured condyle

Consider the following:
What is the patient's general condition?
How well can the mandible function before treatment?
How much is the occlusion affected?
Is this a simple or comminuted fracture?
Is this a unilateral or bilateral fracture?
Are there any associated facial injuries requiring repair?
Is this a fracture dislocation?
What is the fracture configuration? (notably angulation 30 degrees and telescoping 5 mm)
Are there any overlaying lacerations and contamination?
Does the patient have a strong preference?

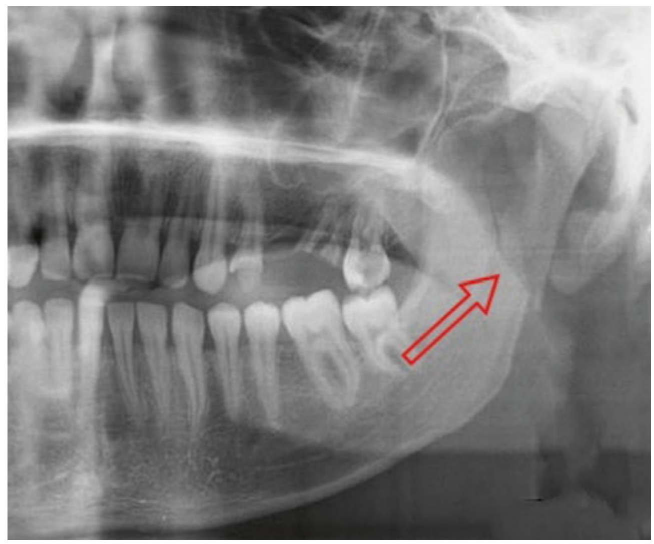

Fig. 6.77 Unilateral fracture of the condyle. There is a degree of overlap of the fragments due to muscle pull (*arrow*). The degree of shortening ("telescoping") and the angulation of the condylar head are important determinants when considering surgical repair

6.7.1 Unilateral Condylar Fractures

In those patients in whom the fracture is minimally displaced and the occlusion is undisturbed, management can be nonsurgical, prescribing rest, soft diet, and simple analgesics. Regular review is essential in the early stages of healing to ensure that the fracture does not "slip" and then heal in the incorrect position.

Unilateral fractures that are significantly displaced and associated with a dysocclusion need to be treated, but not all need to be plated. The main sources of controversy are currently:

- Which fractures should be openly reduced and repaired surgically?
- Which fractures should be surgically repaired based on the fracture displacement, even if the occlusion is only minimally affected—*i.e.*, treatment is based solely on radiographic findings?

Displaced fractures that are not repaired surgically are initially managed with IMF. This is often carried out using wire or (more commonly) elastic IMF, the latter encouraging a more functional realignment of the fragments. IMF is usually applied for around 7–14 days, as prolonged IMF can result in capsular contraction and limitation of mouth opening. Following this, early mobilisation and physiotherapy are required.

Alternatively, and in cases where IMF is contraindicated, fractures may be openly reduced and fixed using miniplates, interosseous wires, or screws. Fractures can be repaired transcutaneously, transorally, or endoscopically. Whatever the approach there is a small risk of facial nerve injury. With careful surgical technique, this can be kept to a minimum.

6.7.2 Bilateral Condylar Fractures

In selected cases, these may be managed following similar principles to unilateral fractures. However, there appears to be a growing trend towards ORIF of at least one if not both sides. These fractures must also be kept under close review until healed. "Telescoping" of the condyles with loss of jaw height posteriorly can lead to the occlusion being propped open at the front—an anterior open bite. This would require secondary surgical correction (see Figs. 6.78 and 6.79).

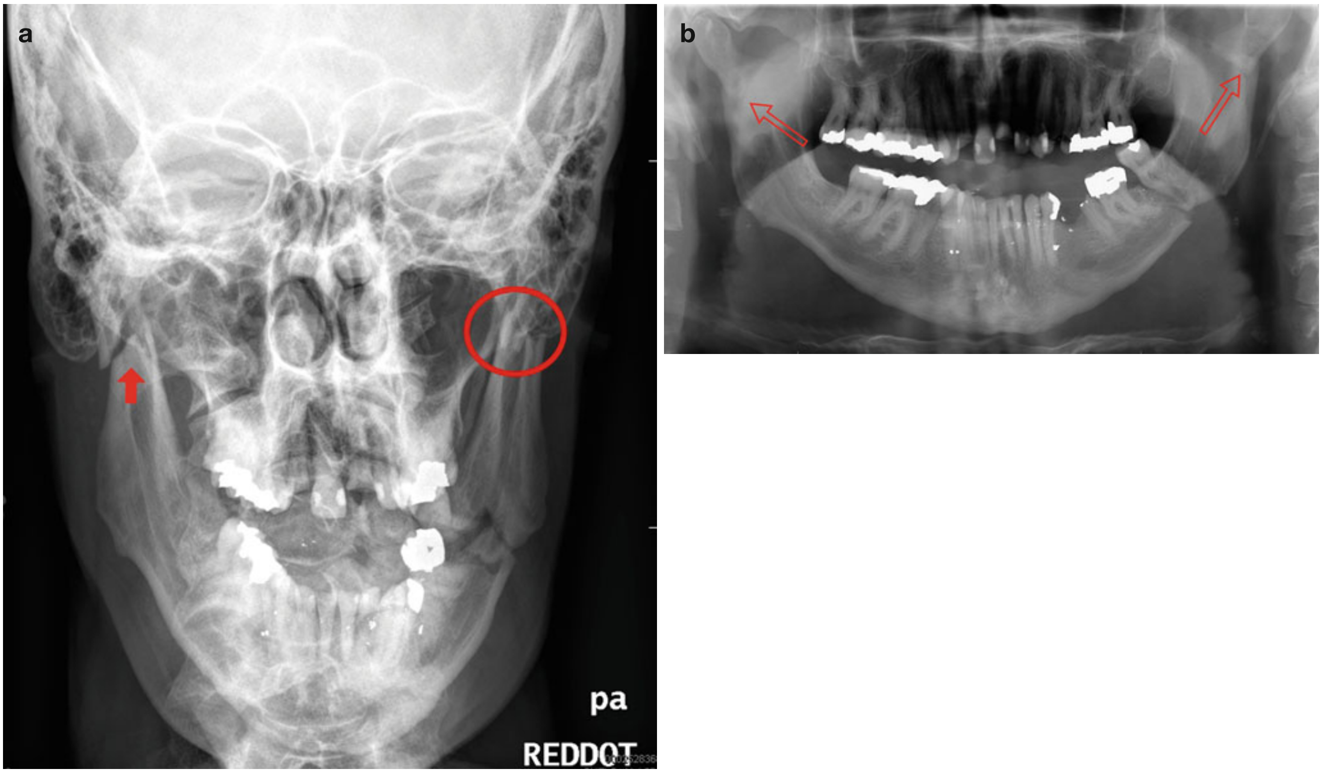

Fig. 6.78 Bilateral condylar fractures and mandibular body fracture. Note the telescoping and angulation of the condylar heads (**a**, **b**)

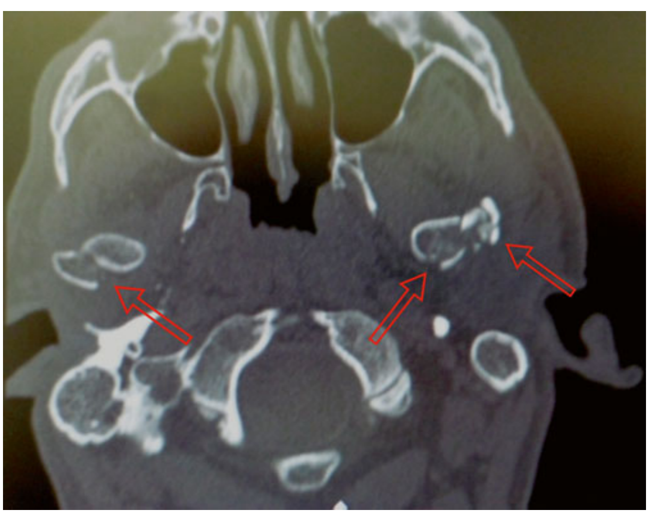

Fig. 6.79 CT evaluation of condylar fractures can be very useful. Comminution (which may not necessarily be seen on plain films) may contraindicate repair

6.7.3 Fracture Dislocation

Occasionally the condylar head may dislocate out of the articular fossa following fracture. This usually requires open reduction. These cases need to be approached with caution. Comminution is commonly associated and makes repair considerably more difficult. CT assessment is advised in all but the simplest of cases (see Figs. 6.80, 6.81, 6.82 and 6.83).

> Bleeding from the external auditory meatus may occur as a result of tearing of the anterior wall by a condylar fracture. However, it may also be a sign of a fractured skull base—be careful in your assessment.

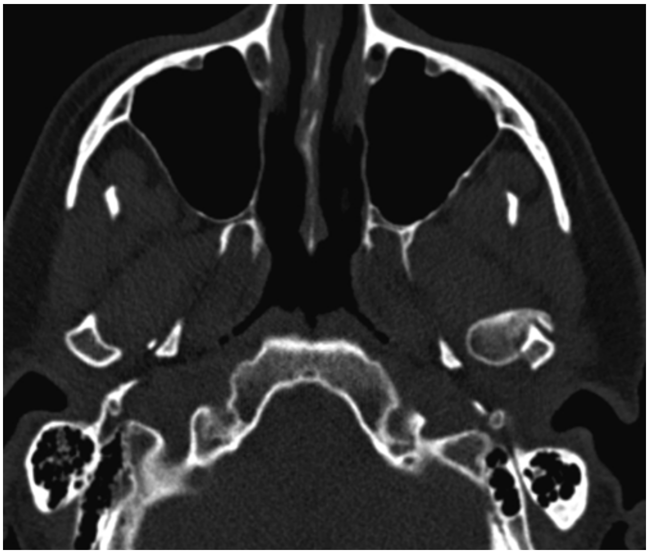

Fig. 6.80 Fracture dislocations of the head require careful assessment. Plain films often do not show the true extent of injury. In this case the head appears fragmented

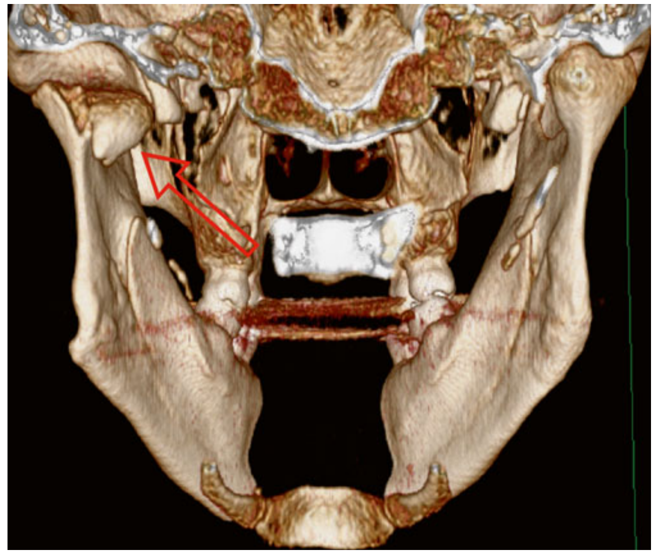

Fig. 6.82 When viewed from behind, the dislocated head is clearly fragmented. Repair would be very difficult for the inexperienced

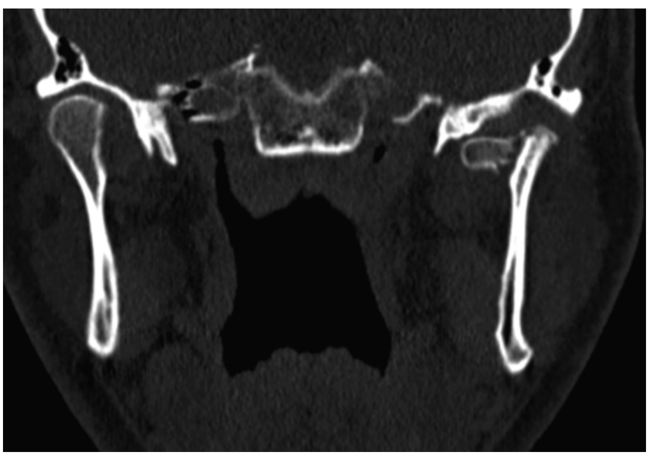

Fig. 6.81 Coronal views confirm multiple small fragments

Fig. 6.83 Bilateral fracture dislocation. The change in position of the condylar head results in greater visibility of its cortex on plain films. This results in a kidney-bean-shaped appearance to the head—an important clue. CT is required

6.7.4 Surgical Repair of Condylar Fractures

Access to the condyle can be transcutaneous or transoral. Endoscopic techniques are also becoming increasingly popular. A number of transcutaneous approaches have been described in the literature. These may be modified slightly, depending on the precise location of the fracture. Whichever approach is taken, it is important that retraction is kept to a minimum. Access is clearly important, but heavy pulling on a retractor to achieve this can result in a traction injury to the branches of the facial nerve. It is probably safer to dissect on a broad front, gently mobilising the tissues, rather

than tunnel down to the fracture and then aggressively retract thereafter.

6.7.4.1 Retromandibular Approach

In the example shown, a retromandibular approach was chosen, since this appeared to be the "shortest route" to the easily palpable fracture of the condylar neck. The position of the fracture was marked on the skin, following review of the radiographs and clinical examination (crepitus is often felt). The skin incision was made approximately one fingerbreadth behind the posterior border of the mandible. A skin flap was then raised, followed by deeper blunt dissection, heading towards the condyle and fracture. Depending on the local anatomy, access to the fracture may be possible by gently lifting the tail of the parotid gland and retracting the masseter muscle. It should be remembered that alcoholic sialosis may preclude this. If this is not possible, a transparotid approach may be necessary. Care is required due to the presence of the lower branches of the facial nerve.

Once the fracture was reached, the periosteum was incised along the condyle and elevated sufficiently to identify and reduce the fracture (see Figs. 6.84, 6.85, 6.86 and 6.87).

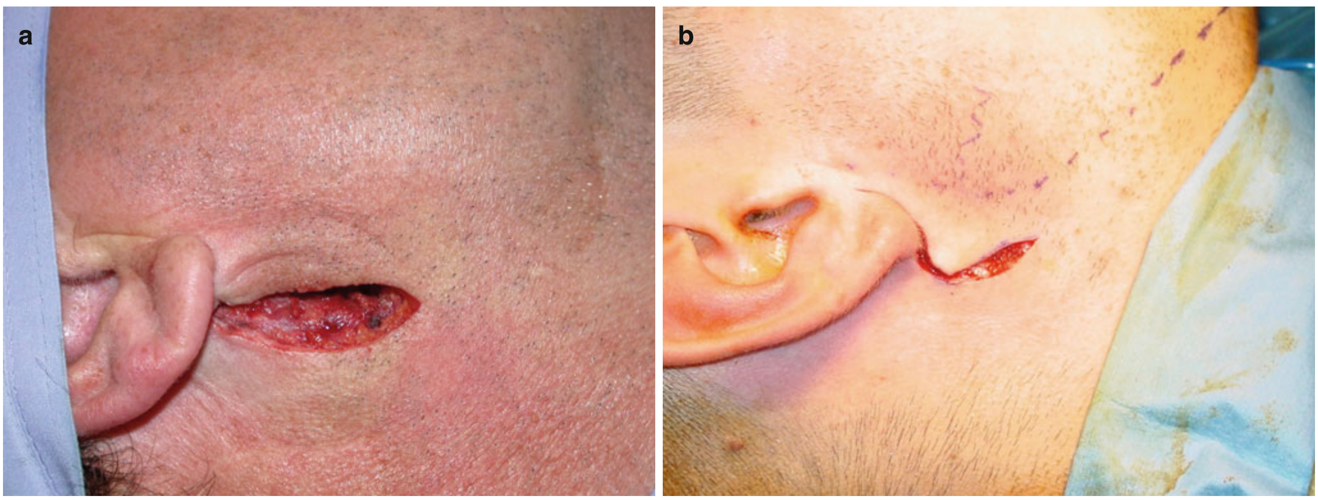

Fig. 6.84 Several skin incisions are possible (linear or curved). All are sited just behind the palpable neck of the condyle (**a**, **b**)

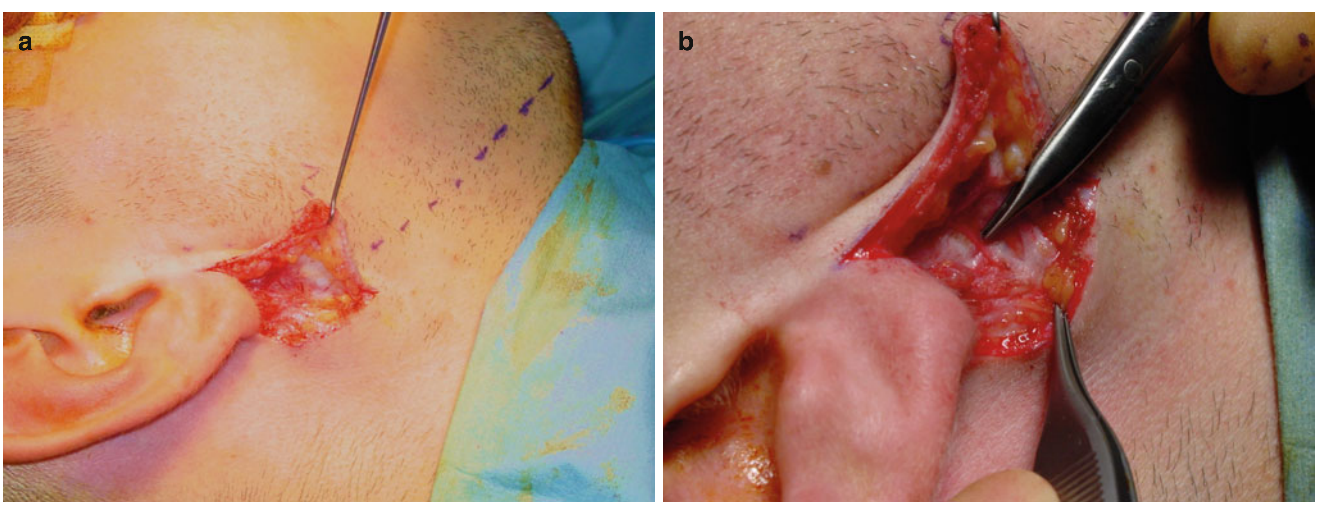

Fig. 6.85 As the flap is raised, the anterior branch of the great auricular nerve is sometimes encountered. Ideally this should be preserved if possible

Fig. 6.86 The tail of parotid is gently retracted forward to expose the masseter. This is incised along the posterior border and the periosteum elevated (**a**, **b**)

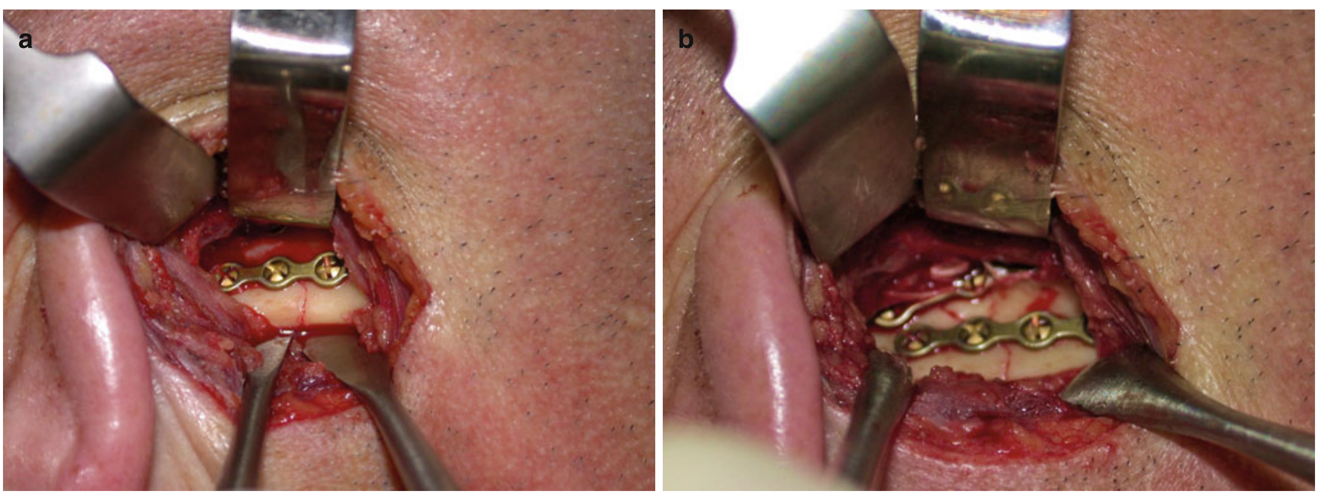

Fig. 6.87 Two plates are required for satisfactory repair (**a**, **b**). This can be difficult, depending on your access. Avoid heavy traction

6.7.4.2 Transparotid Approach

The transparotid approach requires a slightly different route and may provide better access for higher fractures. The fracture position is first identified, marked, and then the skin incision marked in relation to this. This is sited in a suitable skin crease. A full-thickness skin incision is then made. Dissection proceeds towards the fracture, carefully dissecting bluntly, with tenotomy scissors. The parotid fascia is then encountered and easily identified as a fibrous layer. This is divided either with scalpel, or by blunt dissection. Parotid gland is seen as a slightly browner glandular tissue, compared with the superficial lobulated fat. Once the parotid fascia has been breached, meticulous dissection and gentle retraction are essential. With this approach, at least one branch of the facial nerve is often encountered. This can be easily damaged and frequently obscures the surgical field, necessitating gentle retraction when plating the fracture. Dissection continues towards the fracture. The periosteum is then incised and elevated. Although this approach appears to carry the risk of salivary fistula formation postoperatively, this does not appear to be a common problem (see Figs. 6.88–6.97).

Case 1

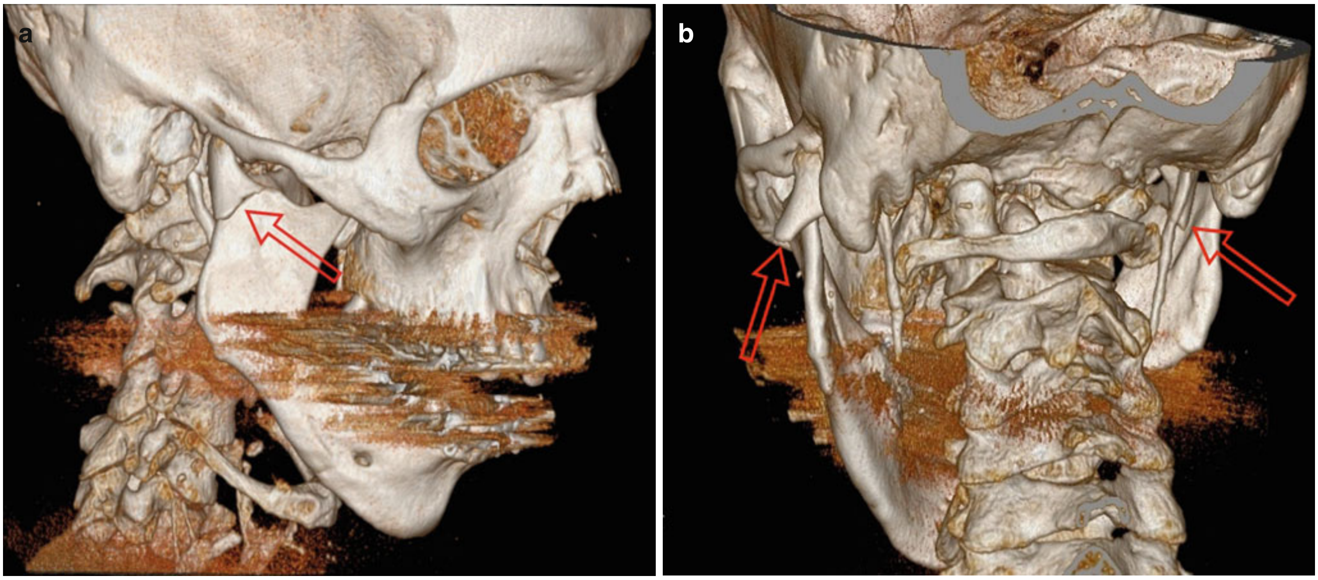

Fig. 6.88 Bilateral fractures of the condyle. The fractures are high and therefore not easily accessible through a retromandibular incision (**a**, **b**)

Fig. 6.89 The skin incision is made in a suitable skin crease (**a**, **b**)

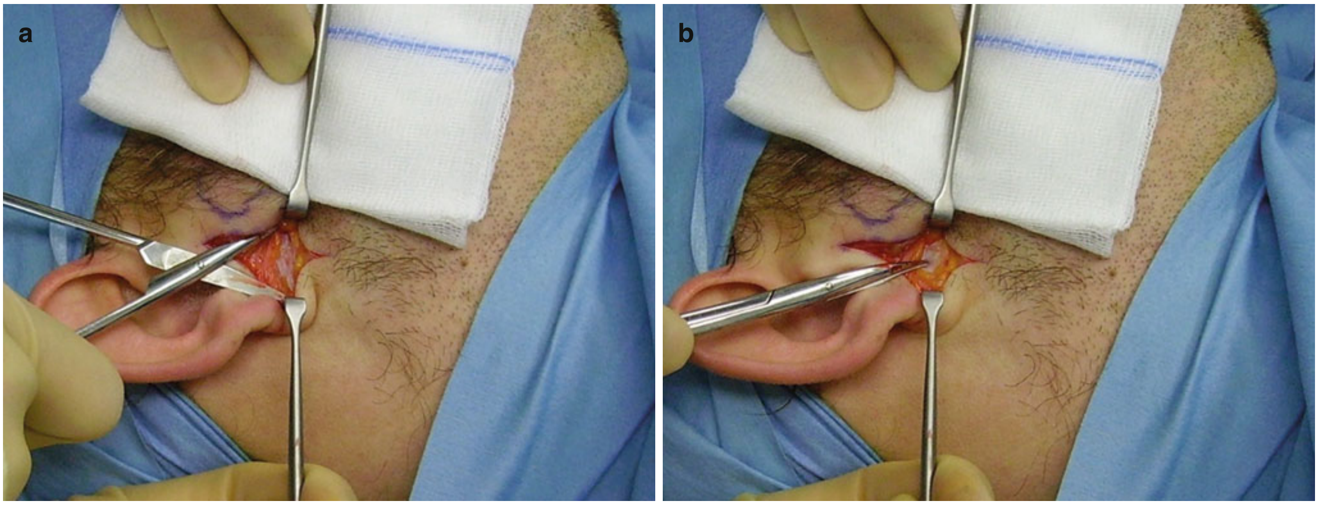

Fig. 6.90 Blunt dissection exposes the parotid fascia (**a**). This is then opened by scalpel or scissor (**b**)

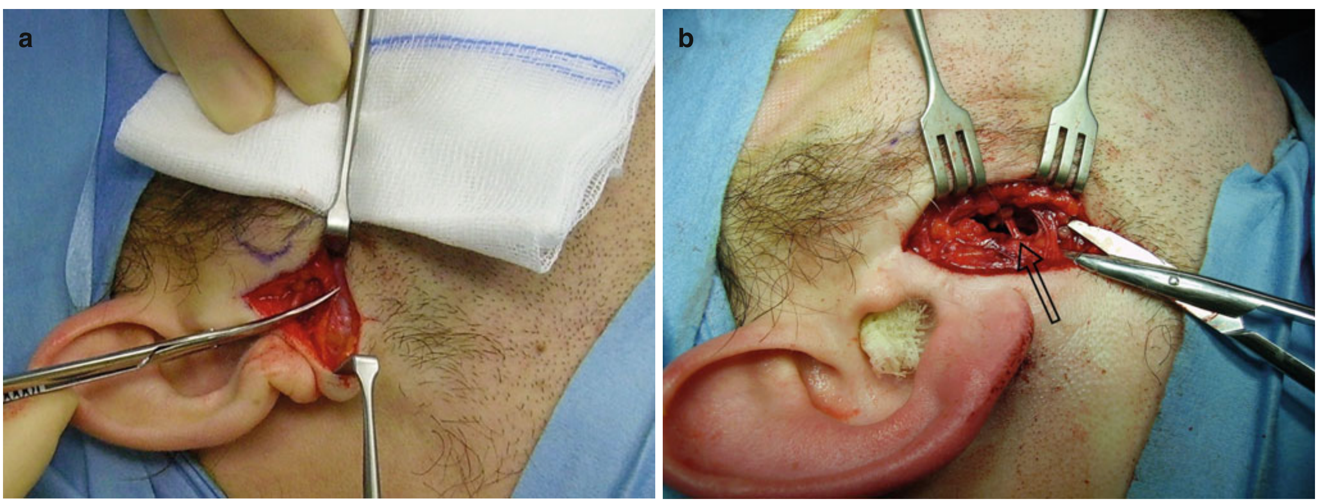

Fig. 6.91 Tenotomy scissors are used to dissect through the parotid gland (**a**). One or more branches of the facial nerve are frequently encountered (*arrow* in **b**). These are gently retracted

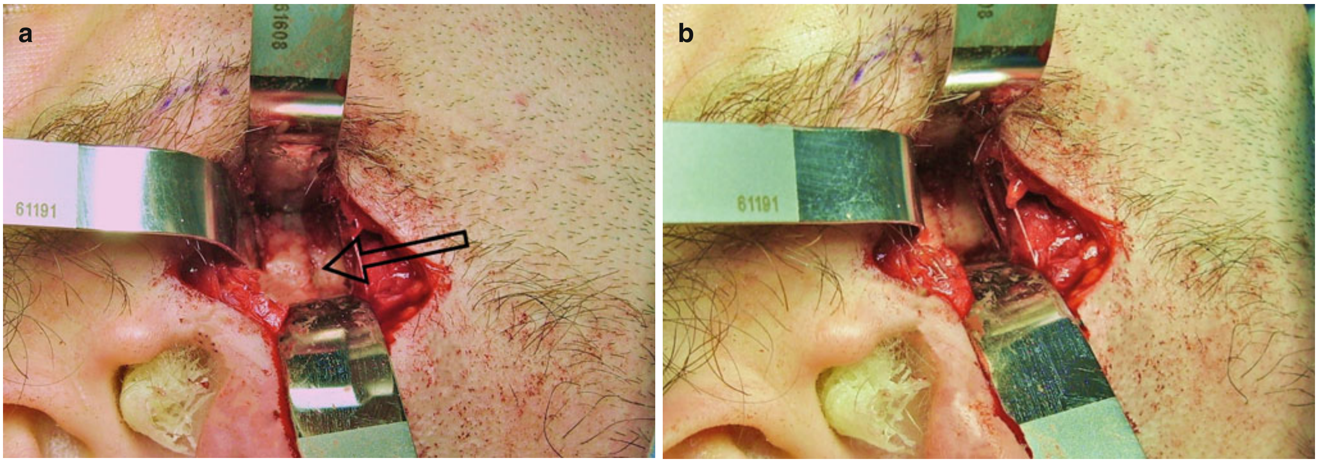

Fig. 6.92 Following periosteal incision and elevation, the fracture is identified (*arrow* in **a**). There is overlap and telescoping of the fragments. The upper fragment lays lateral to the lower (**b**)

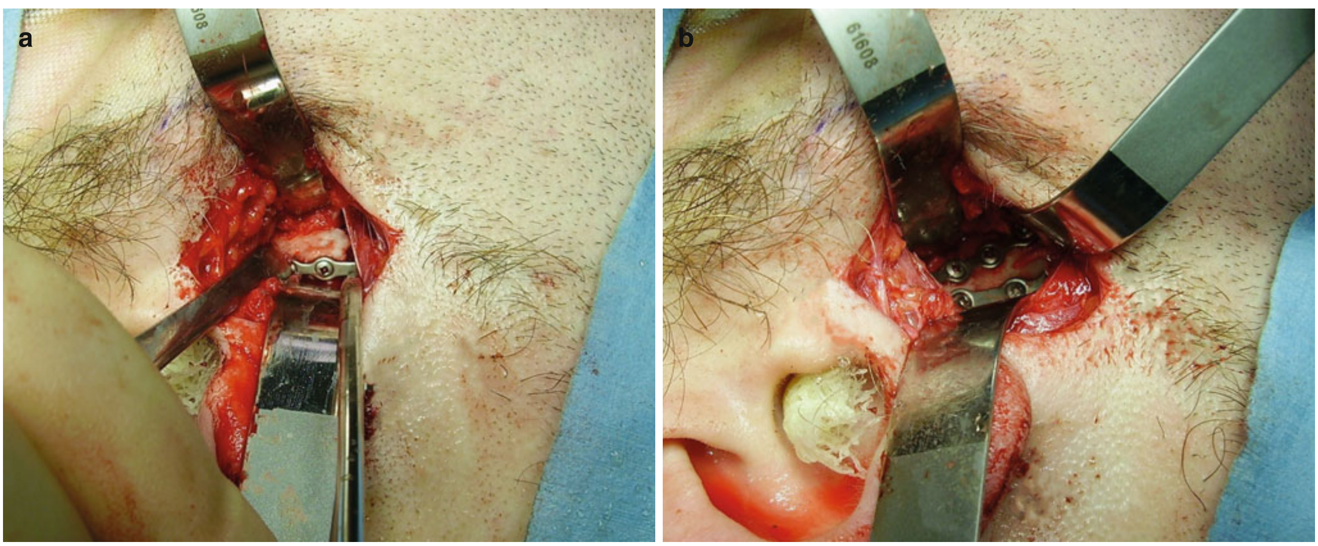

Fig. 6.93 A plate is secured to the upper fragment (**a**). The fracture is then reduced and the lower end of the plate screwed. Two plates are required (**b**)

Case 2

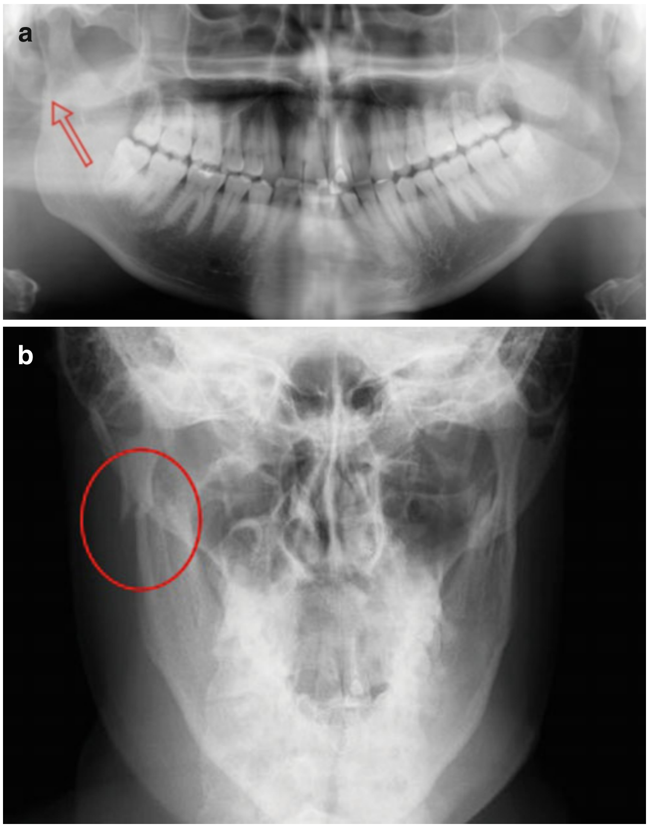

Fig. 6.94 In this example, a slightly lower incision was required. The fracture is most obvious on the posteroanterior view (**a**), highlighting the need for two views at right angles in evaluating fractures (**b**)

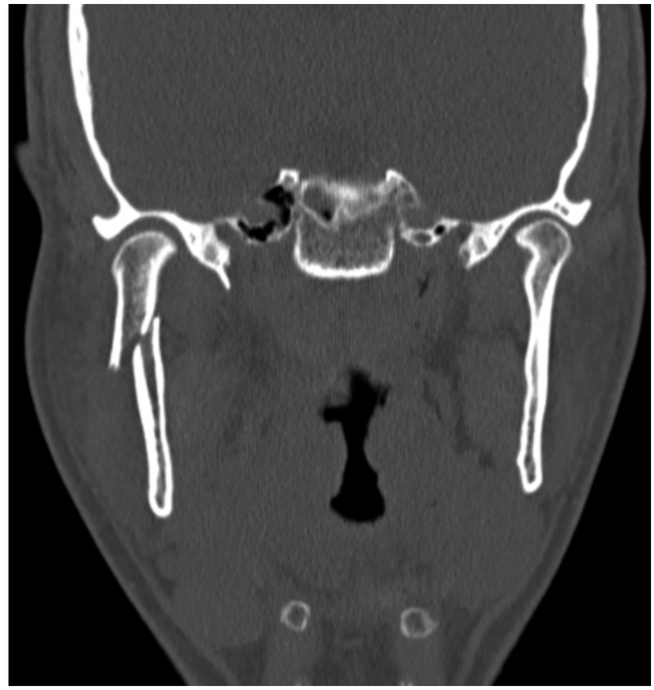

Fig. 6.95 CT imaging confirms a favourable fracture configuration for ORIF. Telescoping is evident and the patient had dysocclusion

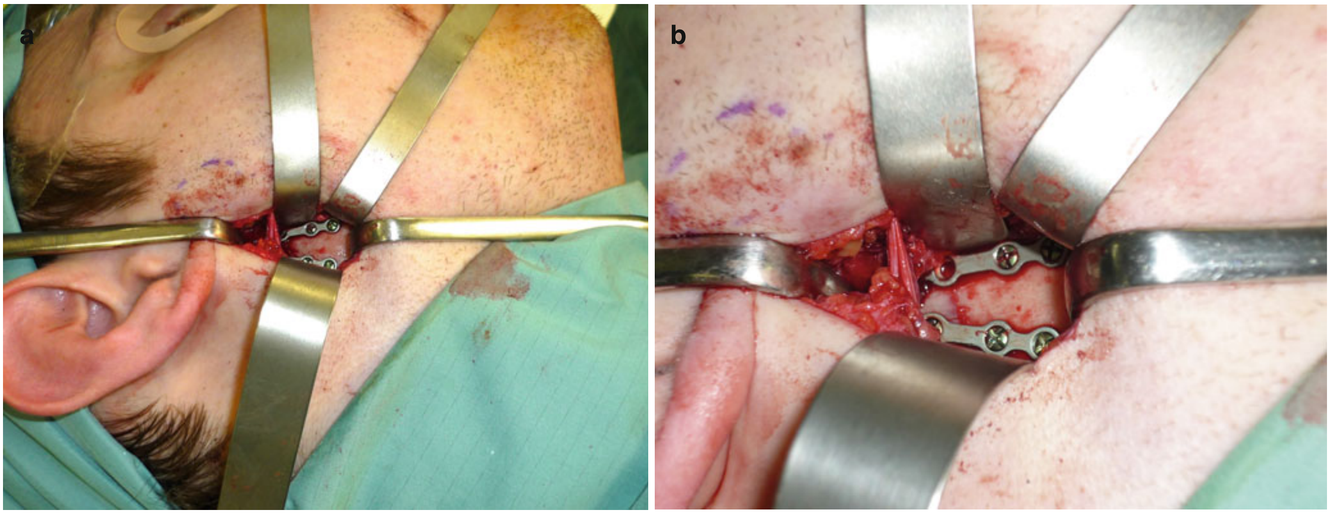

Fig. 6.96 The fracture was exposed through a slightly lower incision than case 1 (**a**). This still required a transparotid approach. The plates can clearly be seen in situ. The buccal branch of the facial nerve can also be seen crossing the wound (**b**). This has been retracted superiorly, but is not under tension

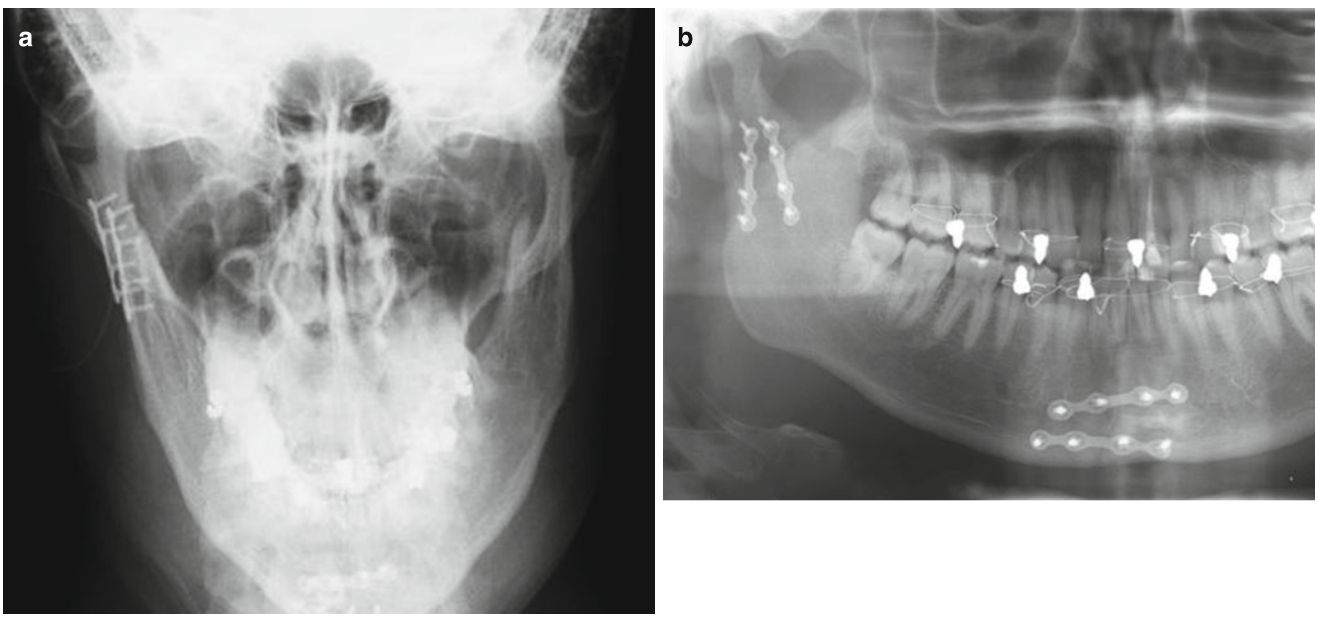

Fig. 6.97 Postoperative films (**a**, **b**)

6.7.4.3 Fracture Reduction

In some cases, fracture reduction can be more difficult than anticipated. This is increasingly more so when delays of more than 2 weeks have occurred. Muscle shortening and early fibrosis act together to resist any attempts to reduce the overlapping fragments. Bleeding is also more significant and obscures the surgical site. Although it is tempting to place an elevator in the fracture gap and lever the fragments apart, this should be resisted—the fracture ends are often delicate. A bite prop placed in the molar region combined with firm manipulation of the mandible can sometimes overcome shortening, but this is not totally reliable and difficult to do if there are missing molar teeth. Alternatively, a hand-held mandibular retractor secured to the lower fragment (ramus) can help retract and manipulate these difficult fractures more effectively. Following exposure of the mandibular ramus, the retractor is secured by two screws just below the fracture site. This facilitates three-dimensional control of the fragments and helps retract the soft tissues. Placement of the retractor is important. It must be secured in such a way that it does not

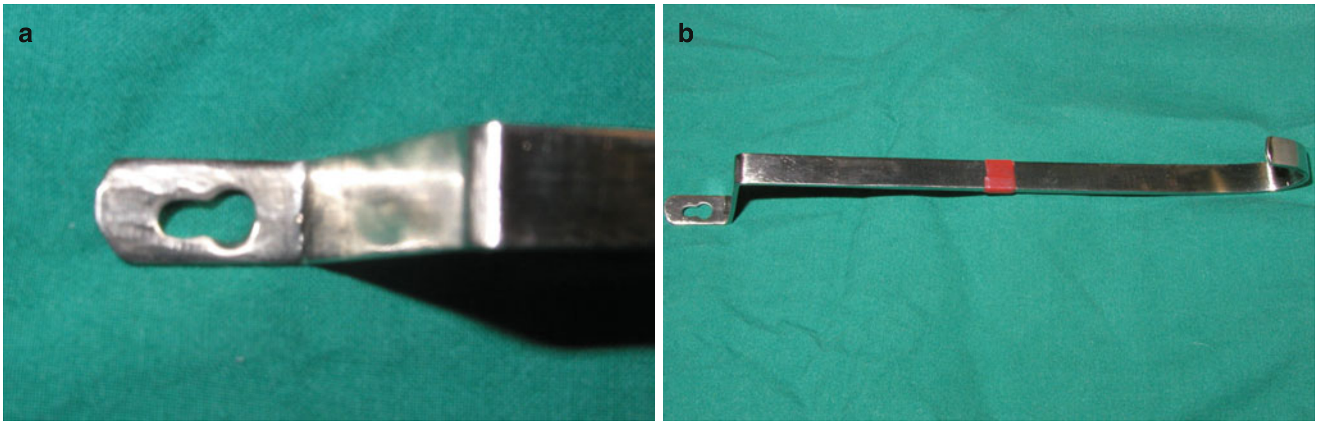

Fig. 6.98 A custom-made ramus retractor (**a**, **b**)

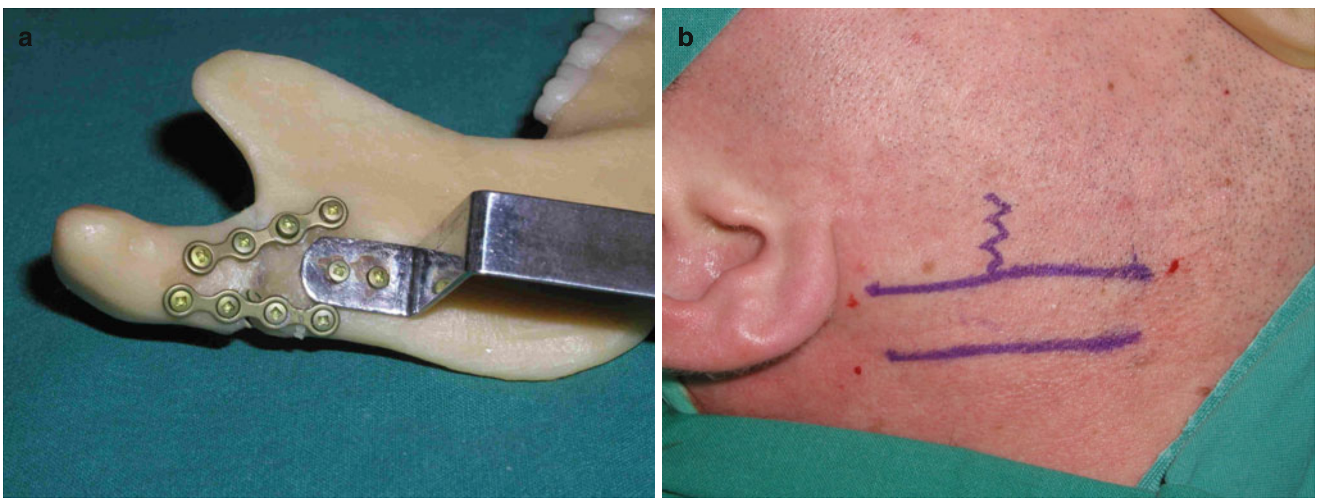

Fig. 6.99 The retractor is secured to the ramus as shown, to allow retraction downwards (**a**, **b**)

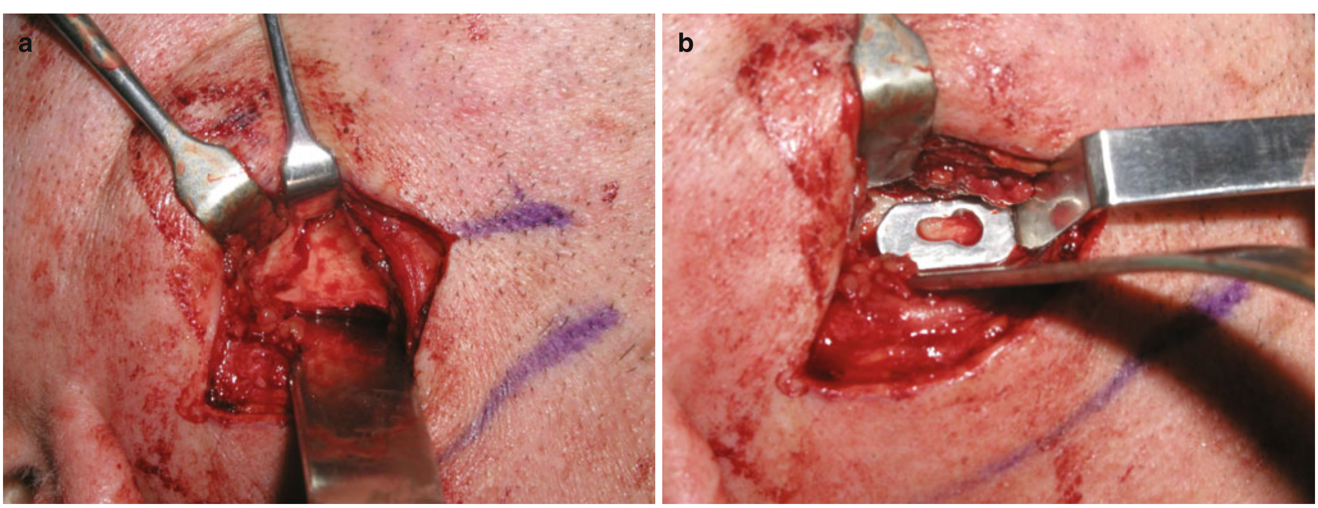

Fig. 6.100 Fracture exposure (**a**) and placement (**b**)

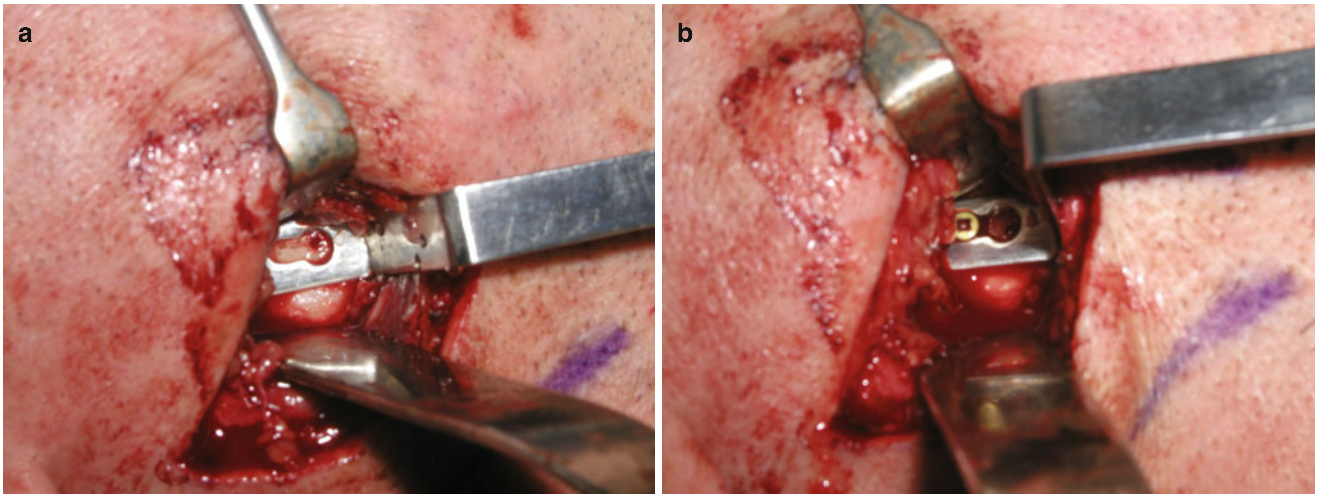

Fig. 6.101 Temporary screw fixation (**a**, **b**)

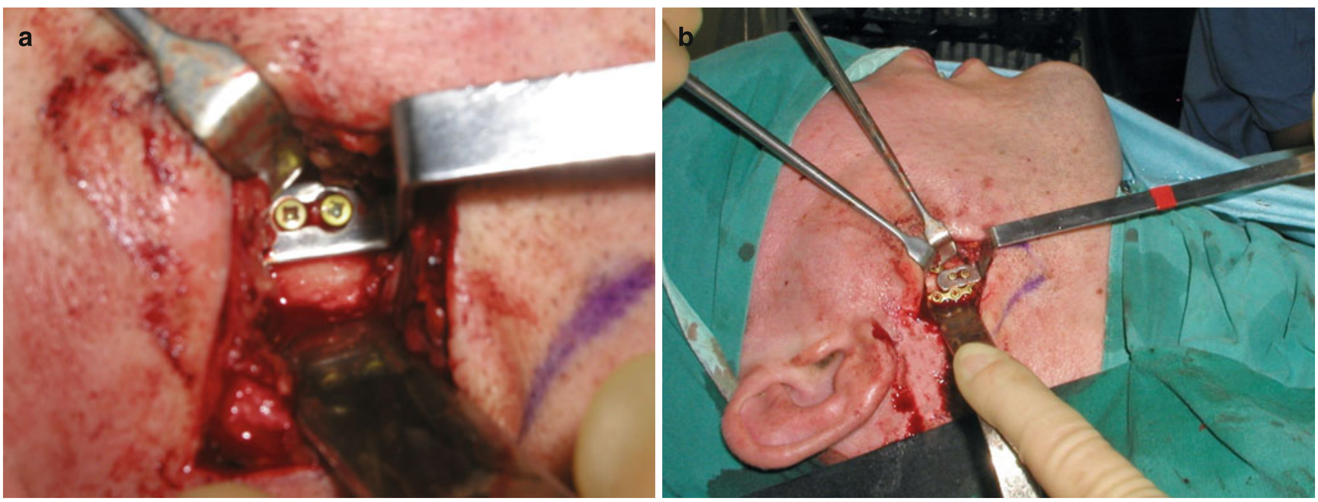

Fig. 6.102 Once secured (**a**), the ramus can be pulled to length (**b**)

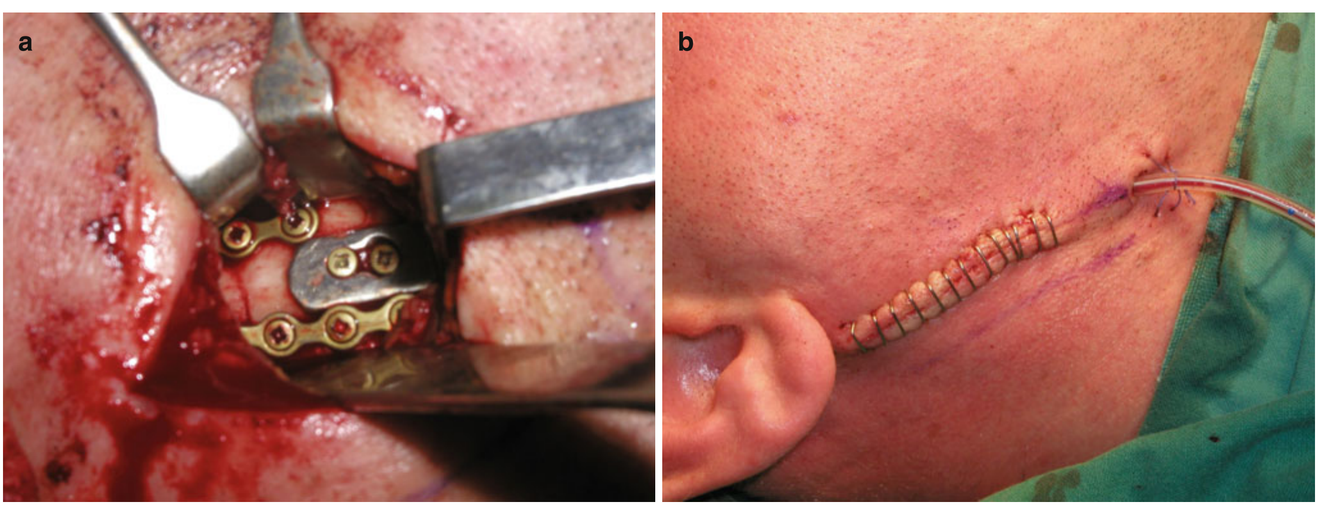

Fig. 6.103 Fixation complete before the retractor is removed (**a**, **b**)

hinder placement of the fixation plates. Following internal fixation of the fracture, the retractor and screws are removed (see Figs. 6.98–6.103).

6.7.4.4 Plate Fixation

Most surgeons agree that if internal fixation is undertaken, two plates are required. Technically this can sometimes be difficult. Custom designed plates are now available (see Fig. 6.104).

Whatever surgical approach is undertaken, the wounds are closed layers. A small suction drain may be placed to minimise haematoma collection post operatively.

6.7.4.5 Extended Approach for Fracture Dislocation

This is a much more extensive procedure that may occasionally be required in difficult cases of fracture dislocation (notably if treatment has been delayed). In essence, it is a combination of an open surgical approach to the TMJ, with that for the condylar neck. The upper part of the dissection provides direct access to the head of the condyle, enabling direct manipulation and repositioning. If the condyle is manipulated, it is important not to damage its soft articulating surface. This procedure is not required in every case of fracture dislocation. Often the head of the condyle can be reduced from one of the lower approaches just described. However, in delayed cases, reduction becomes much harder and this direct approach may be required. Needless to say, the facial nerve is at a much higher risk of injury (*see* Figs. 6.105–6.114).

Fig. 6.104 Custom-designed plate

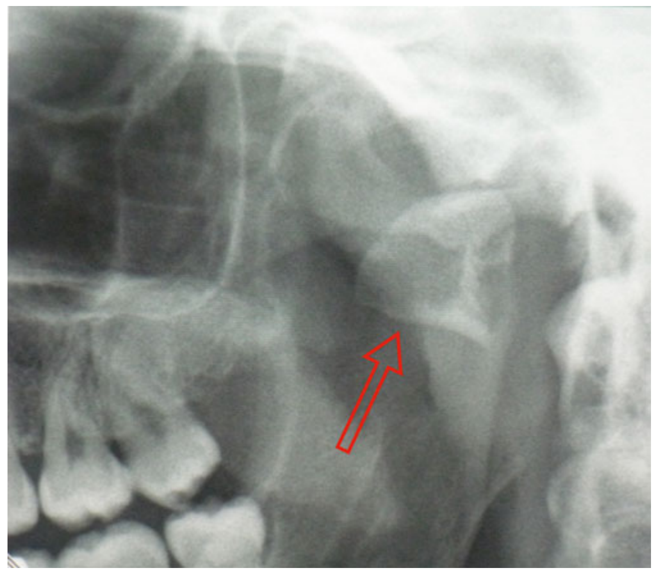

Fig. 6.105 Fracture dislocation of the condyle on OPT

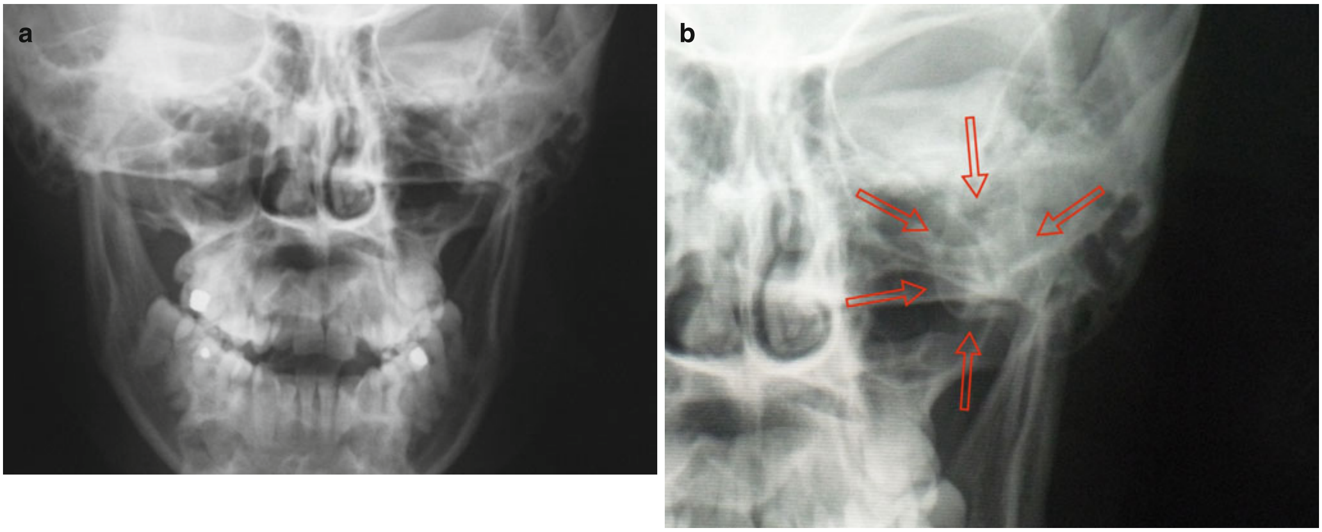

Fig. 6.106 Fracture dislocation of the condyle on PA film (**a**, **b**)

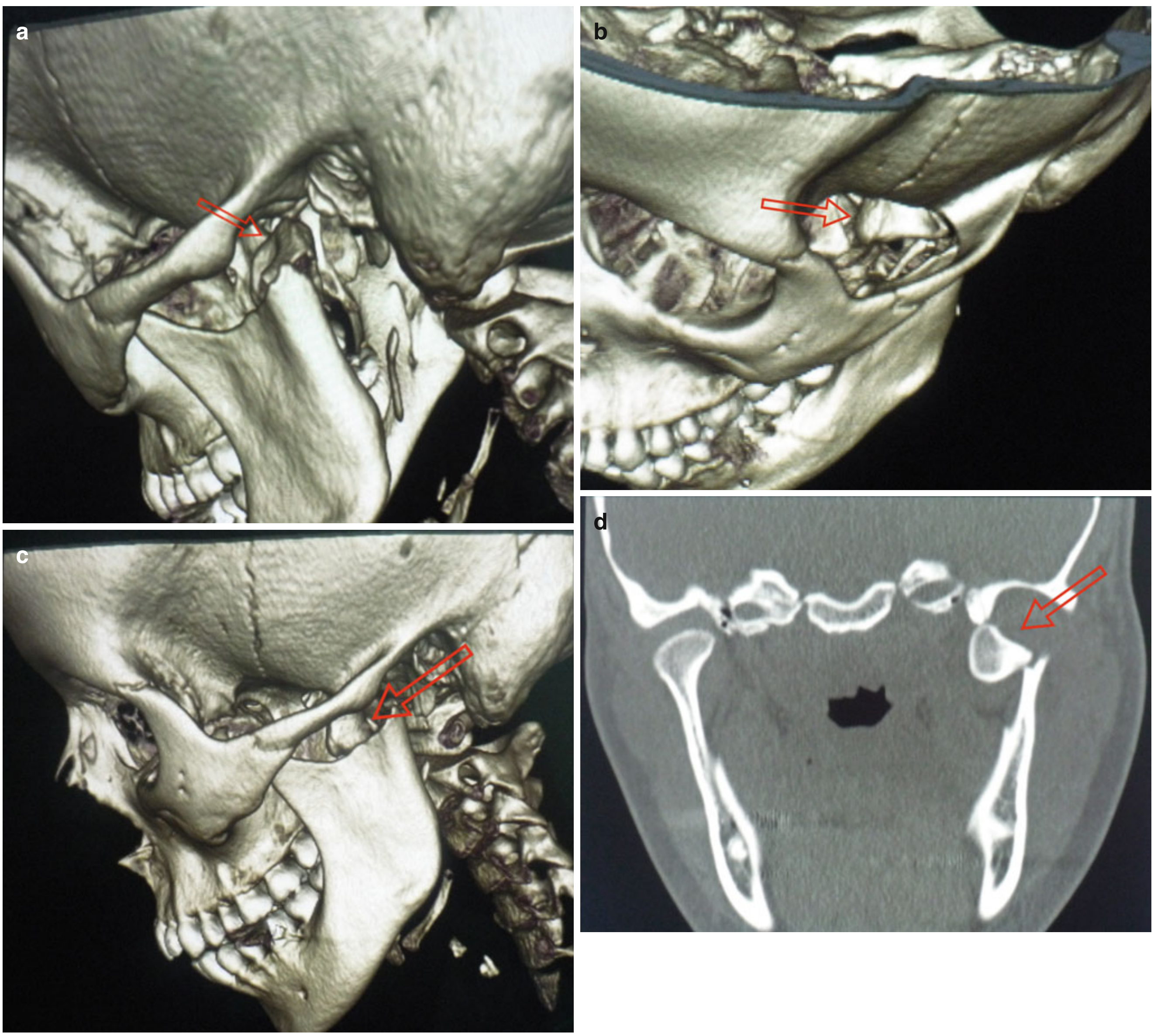

Fig. 6.107 CT appearances. The fracture is high, but the head is intact. A difficult case (**a**–**d**)

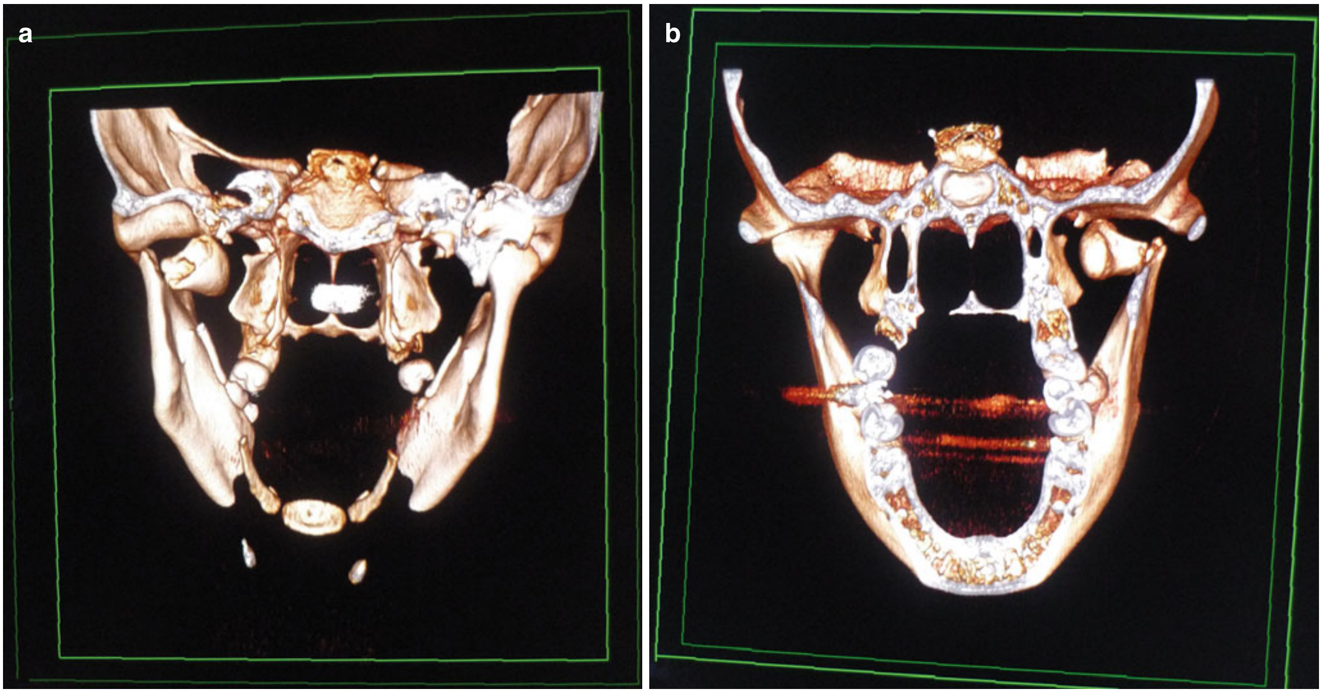

Fig. 6.108 Anterior and posterior views showing extent of dislocation (**a**, **b**)

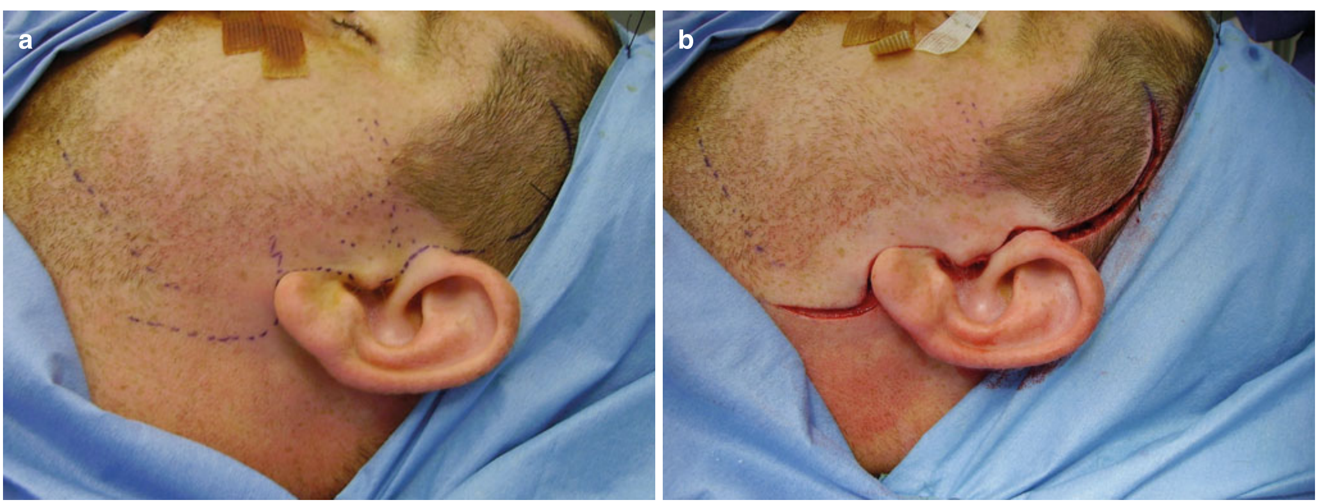

Fig. 6.109 The surgical approach required is a combination of the preauricular and retromandibular approaches (**a**, **b**). To understand this approach, review the preauricular dissection described in the chapter on coronal flaps

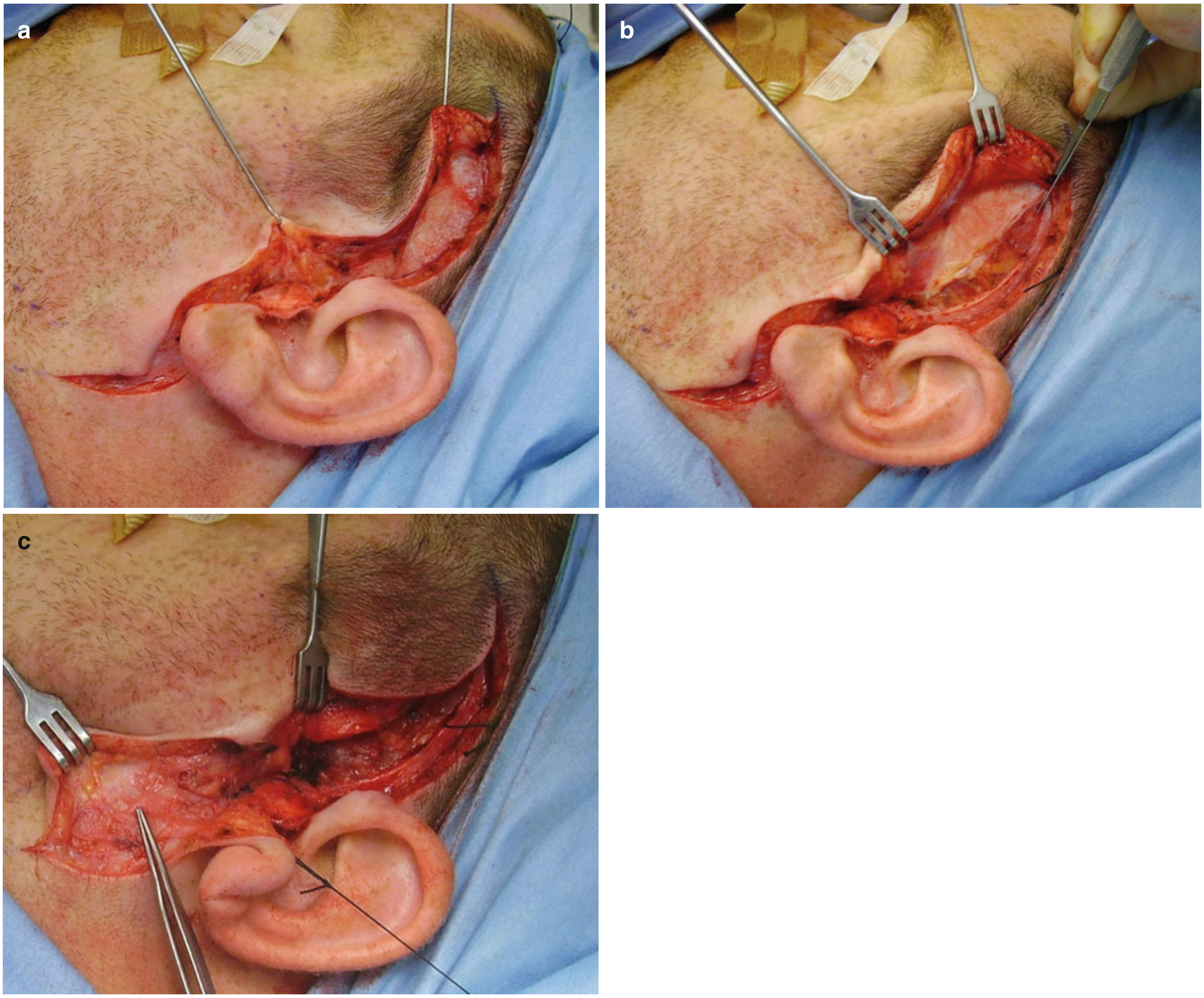

Fig. 6.110 Following skin incision (**a**), the temporalis flap is incised (**b**, **c**)

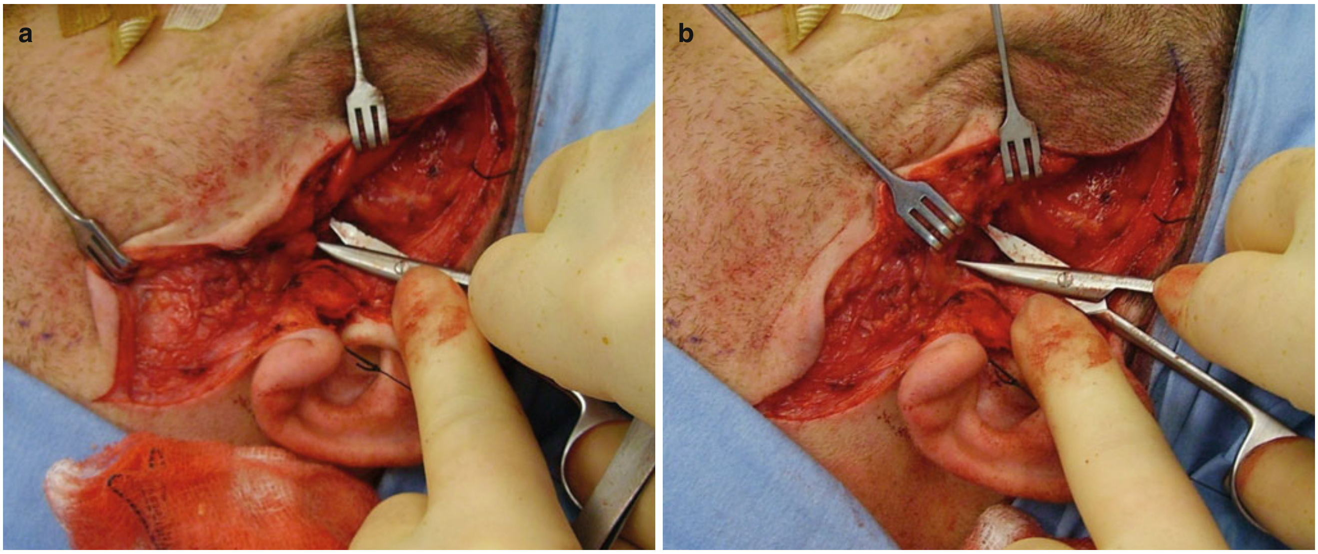

Fig. 6.111 The fascia is elevated (**a**), exposing the arch and approaching the capsule of the TMJ from above (**b**)

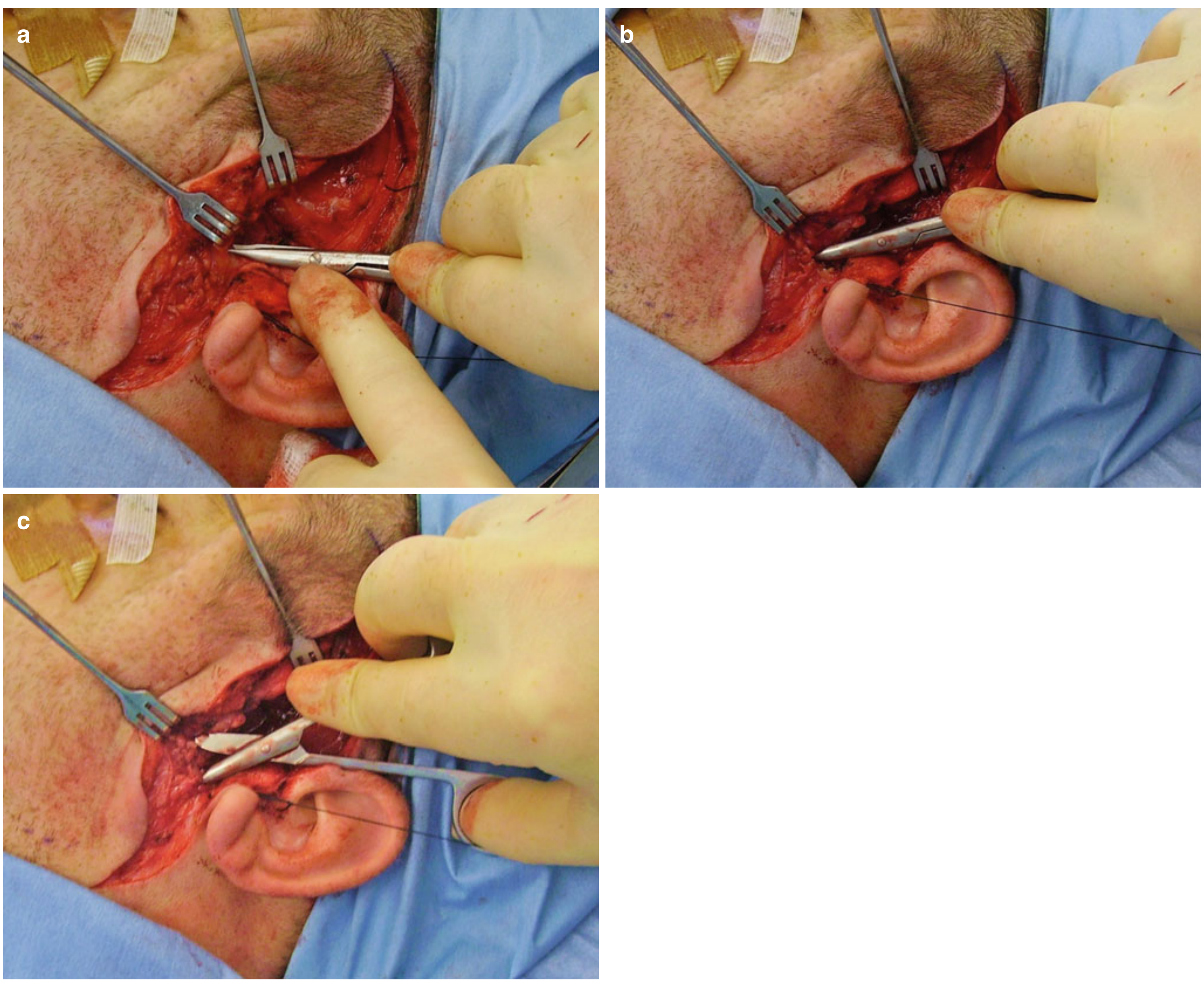

Fig. 6.112 The lower dissection mobilises or divides the parotid fascia as required to expose the lower fragment (**a**–**c**)

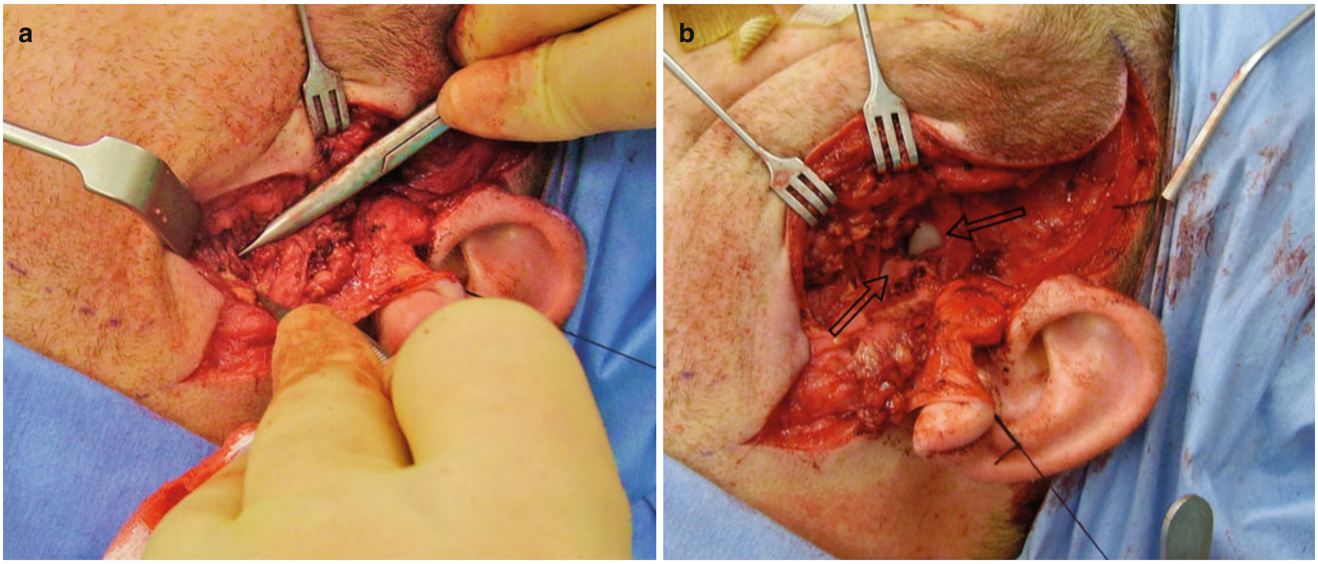

Fig. 6.113 Branches of the facial nerve are frequently encountered (**a**). These are gently retracted. The upper and lower halve of the dissection are gradually reflected forward to expose the dislocated head and lower fragment (*arrows* in **b**)

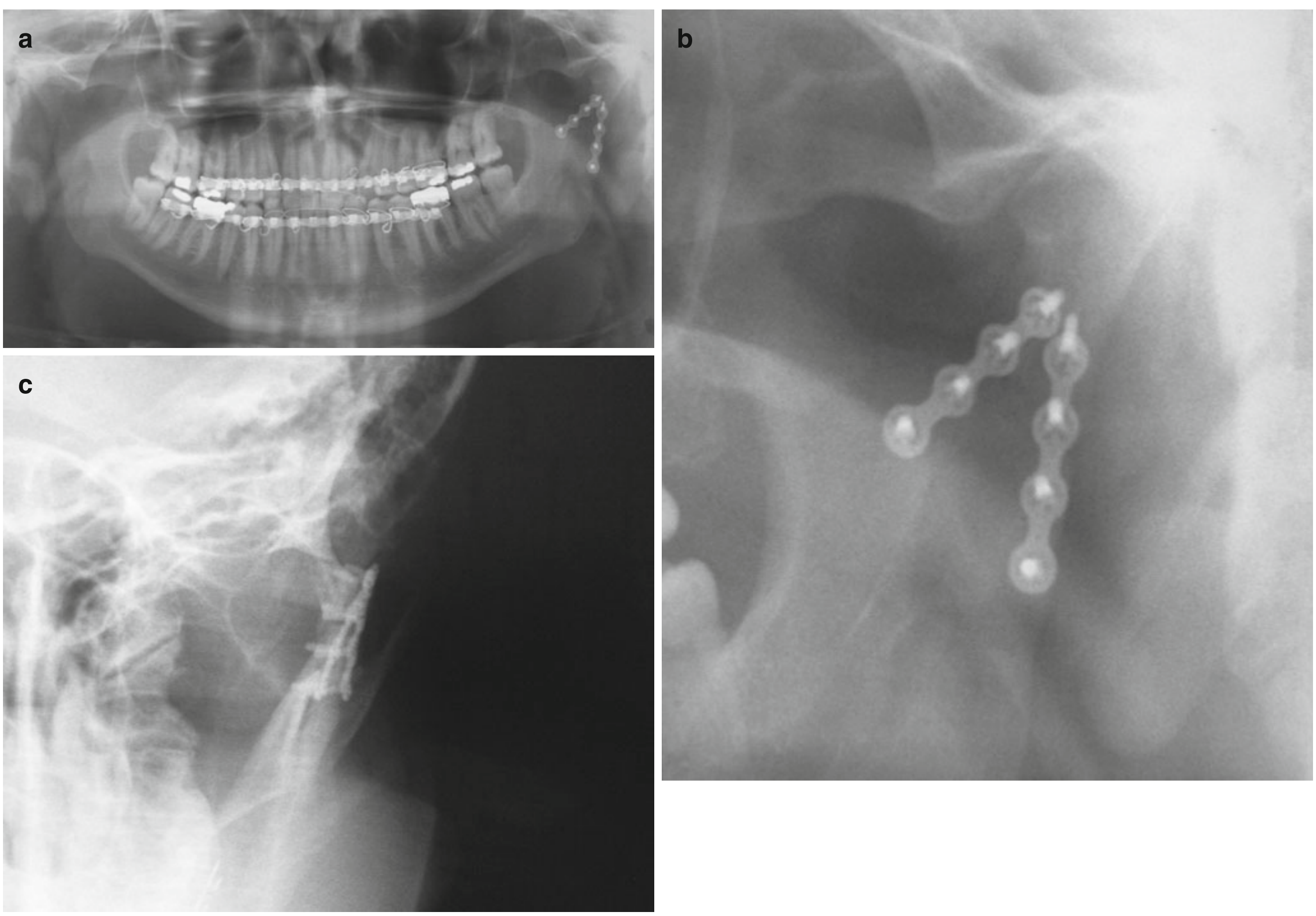

Fig. 6.114 Postoperative film (**a**–**c**)

6.7.4.6 Endaural and Retroauricular Access

Access to the condyle may also be possible by taking a direct route through the external auditory meatus. With the endaural approach, the incision passes deep to the tragus, so that the anterior wall of the meatus is divided and reflected forward. A retroauricular incision with transection of the entire meatus has also been described in the literature. These approaches are reported to provide good access to the head of the condyle.

6.7.4.7 Endoscopic Assisted Repair

Minimally invasive endoscopic repair of facial fractures has been available for around a decade now, but is a highly specialised skill. It has been reported to offer less morbidity and operating time, as well as quicker patient recovery. But like all techniques, there is a learning curve. Current applications include the management of low condylar fractures, orbital fractures, frontal sinus fractures, and fractures of the zygomatic arch.

Case selection is very important and this technique is reported to work best for low condylar fractures with lateral displacement of the upper fragment. Endoscopic repair is more difficult for medially displaced fractures, although it is not impossible. Comminuted and high-level fractures are perhaps best avoided, but this depends on the skills of the surgeon.

The main advantages of this technique are the reduced risks to the facial nerve, and improved scarring, compared with percutaneous techniques. Transoral access to the fracture is required.

Intermaxillary fixation is usually required during repair and postoperatively. An incision is made along the anterior border of the ramus. The periosteum (and masseter) is then elevated carefully to avoid tearing (and subsequent bleeding which may obscure visualisation). When the cavity is large enough, the endoscope can then be passed. Elevation is continued until the fracture is identified. Periosteum is raised only from the lateral surface. Downward traction at the angle of the mandible enables laterally displaced upper fragments to be pushed into place. Medially displaced proximal fragments need to be reduced laterally with an elevator placed through the incision. A stab incision in the overlaying skin is then placed. This allows the transbuccal trocar to be placed through the cheek. This portal will provide access for drilling and screw placement. Once the fracture has been reduced, one (or preferably two) plates are secured. The wound is then irrigated and closed (see Figs. 6.115–6.121).

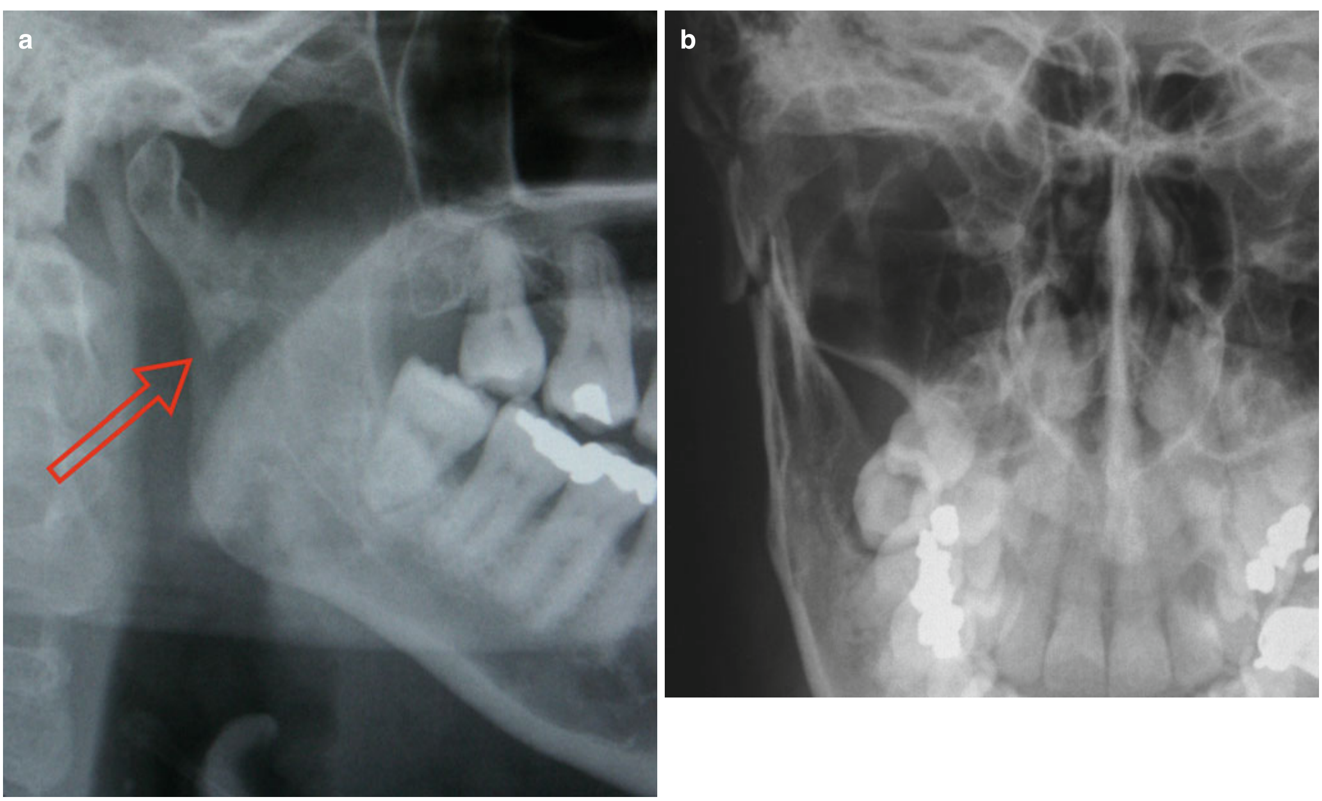

Fig. 6.115 Low-level fracture of condylar neck (**a**, **b**). A good case for endoscopic repair

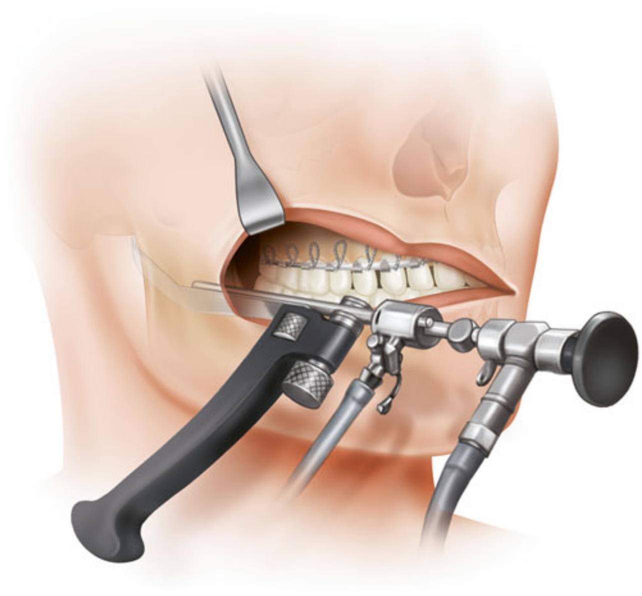

Fig. 6.116 See text for detail. The endoscope is placed through a transoral incision. Drilling and screwing are done transcutaneously

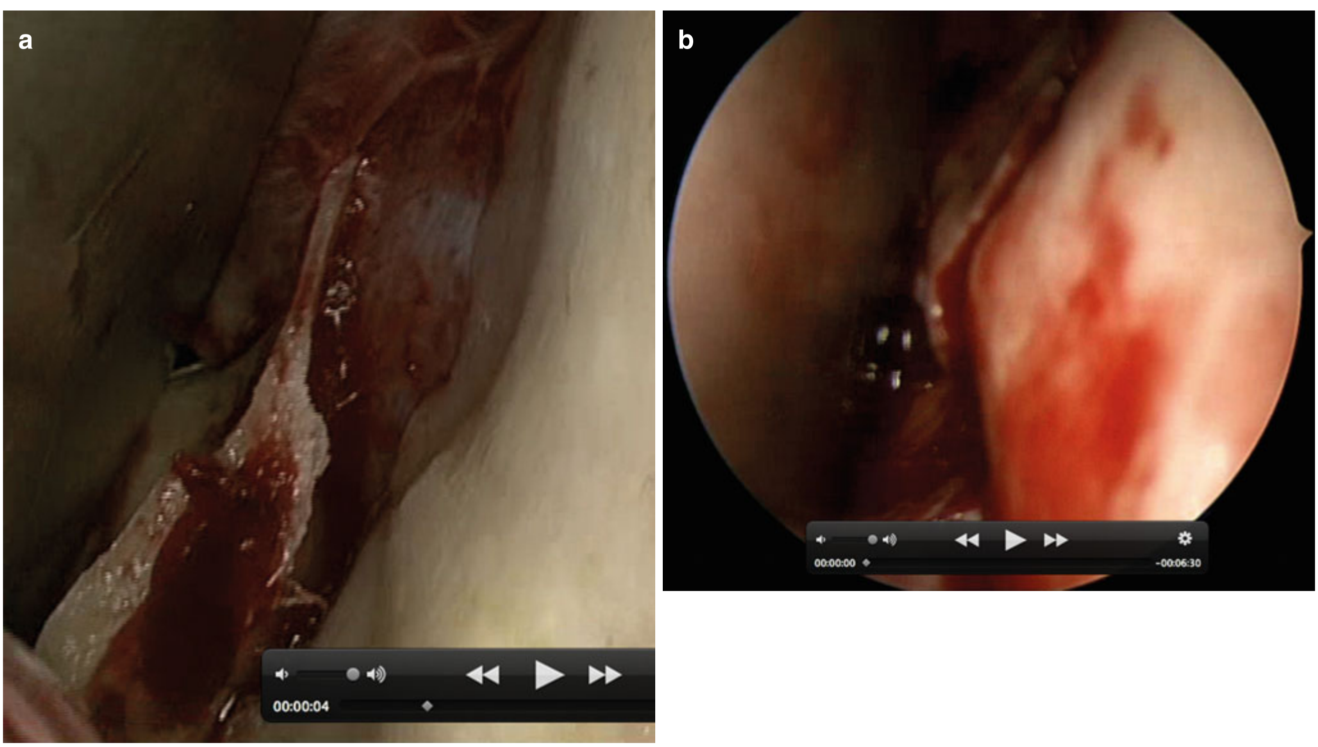

Fig. 6.117 Following placement of the endoscope, the fracture can be clearly visualised. It can also be easily reduced using an elevator (**a**, **b**)

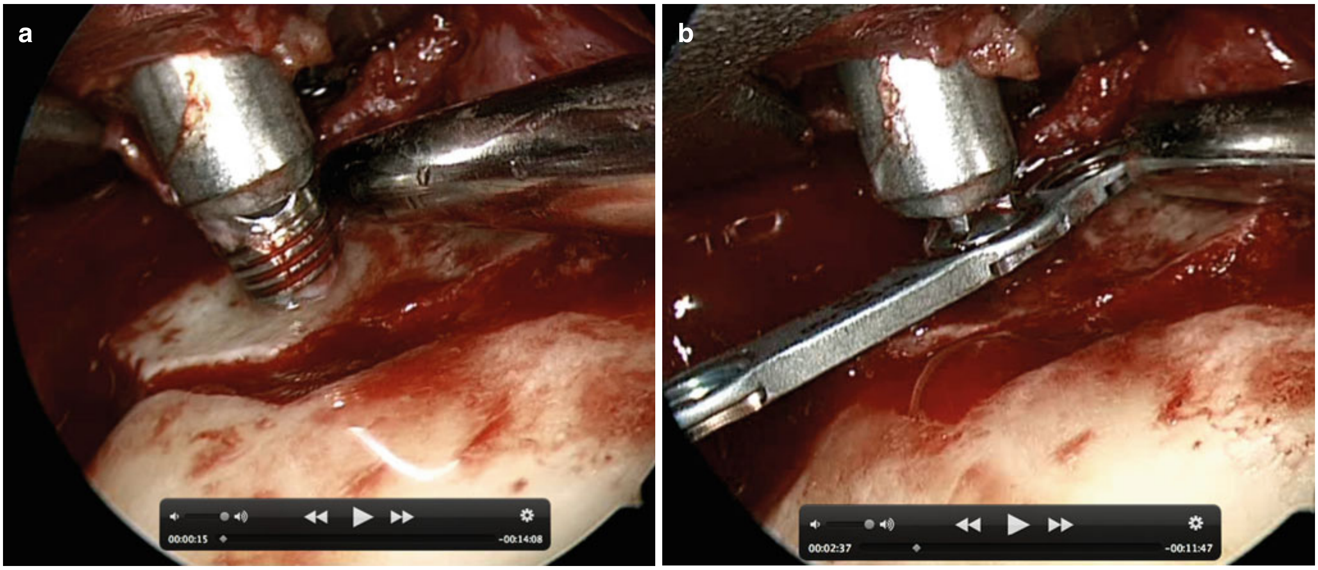

Fig. 6.118 The first hole is drilled in the upper (proximal) fragment and the plate secured with a screw (**a**, **b**)

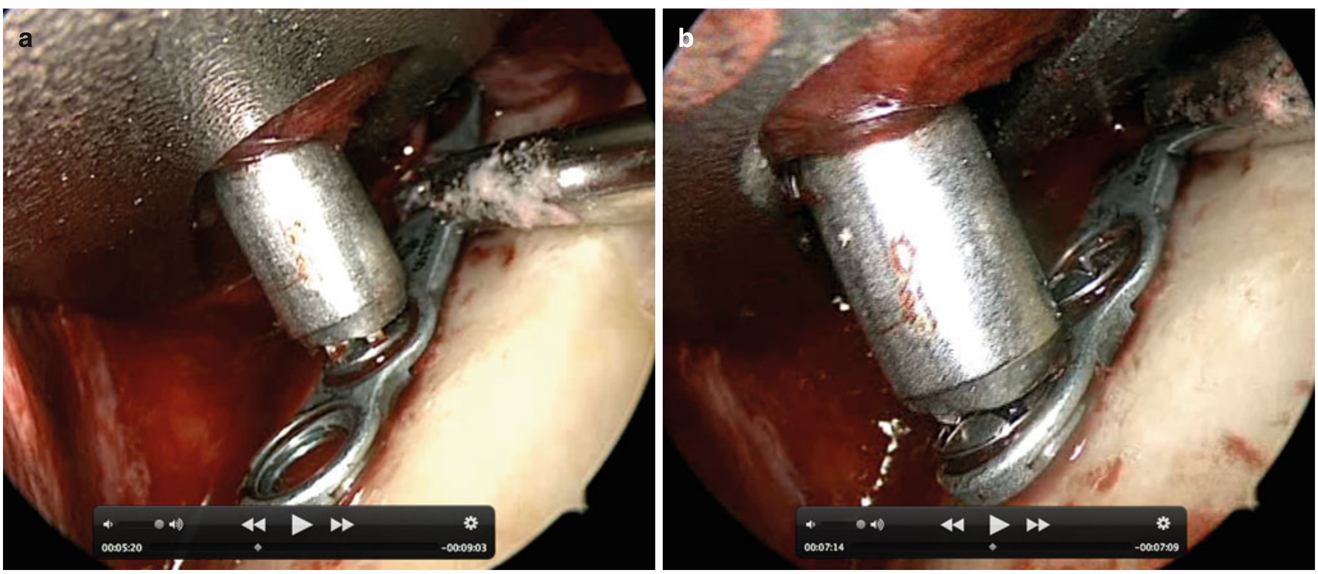

Fig. 6.119 The fracture is then reduced (also using IMF) and a screw placed on the other side. This holds the reduced fragments in place, which can then be inspected (**a**, **b**)

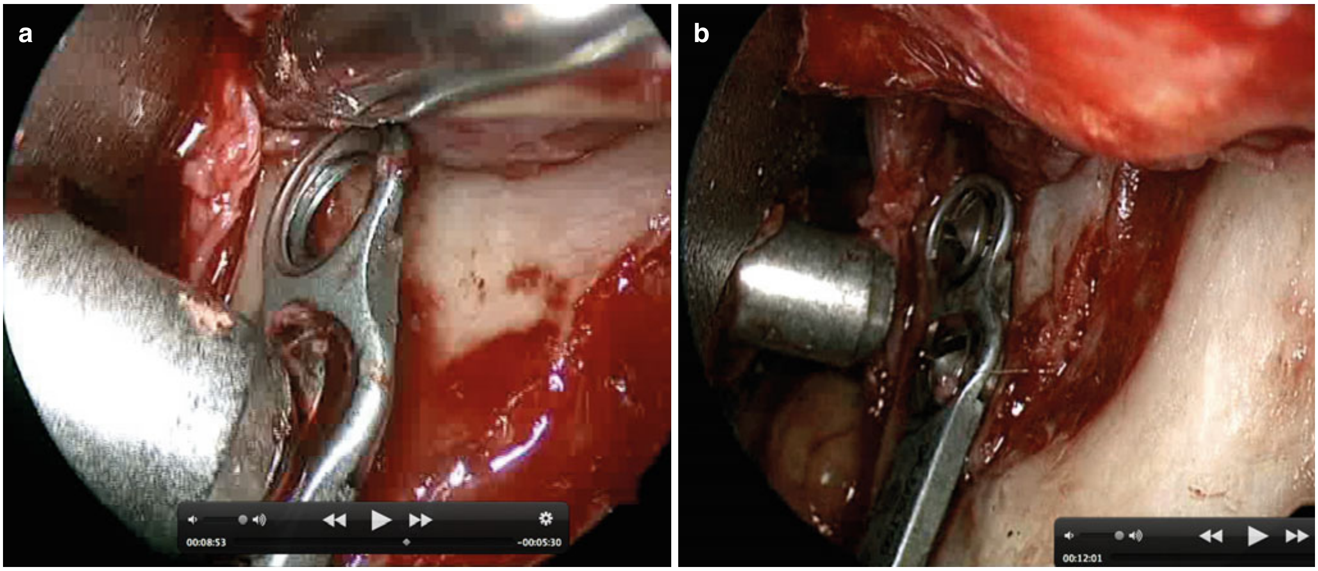

Fig. 6.120 The two remaining screws are then secured, either end of the plate (**a**, **b**)

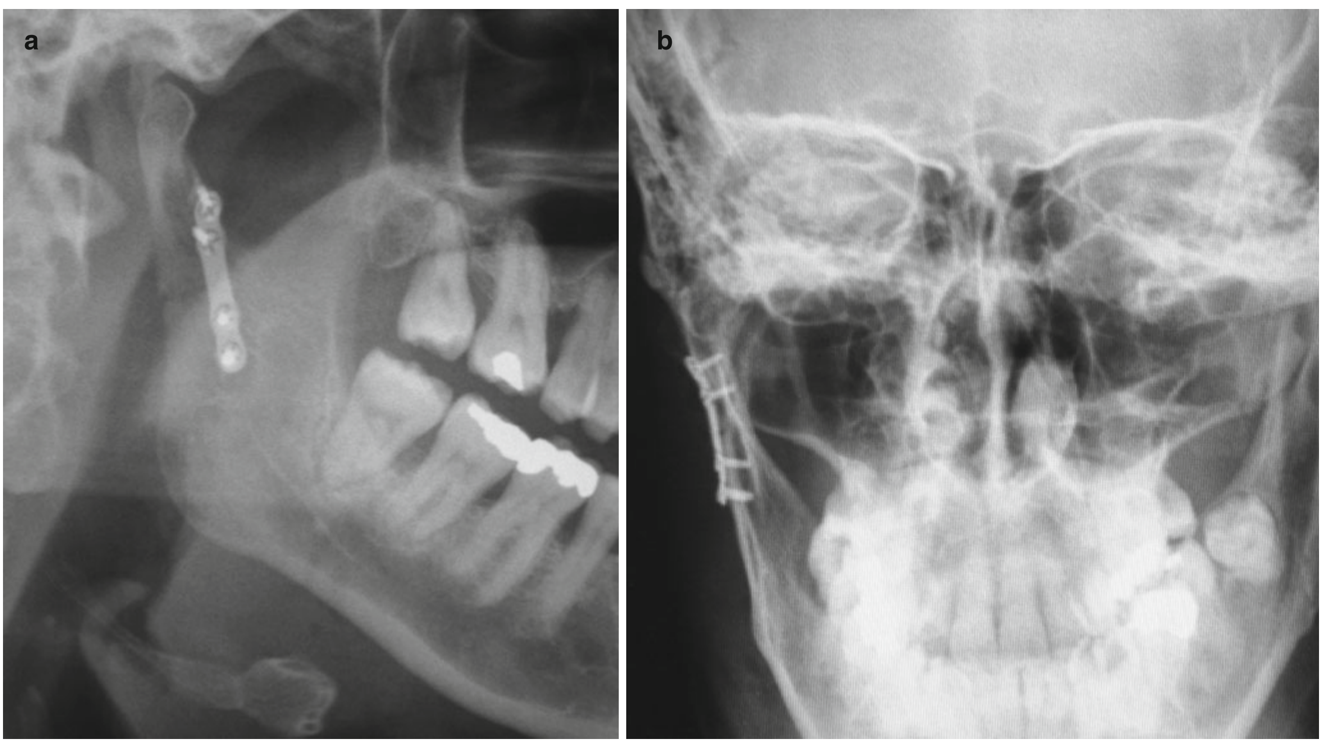

Fig. 6.121 Postoperative radiographs. The plate, fracture, and occlusion are then carefully inspected to ensure good alignment, reduction, and function (**a**, **b**)

6.7.4.8 Lag Screw Techniques

These can sometimes be used in the management of condylar head fractures, usually when the medial pole has "split away" from the remainder of the head. The general principles of the lag screw technique have already been described. This is a highly specialised technique and needs careful case selection.

The Eckelt lag screw technique is perhaps now more of historical interest, although still worth knowing about. This and other variants follow similar principles and require precise manipulation of the fragments if anatomical reduction is to be achieved (see Fig. 6.122).

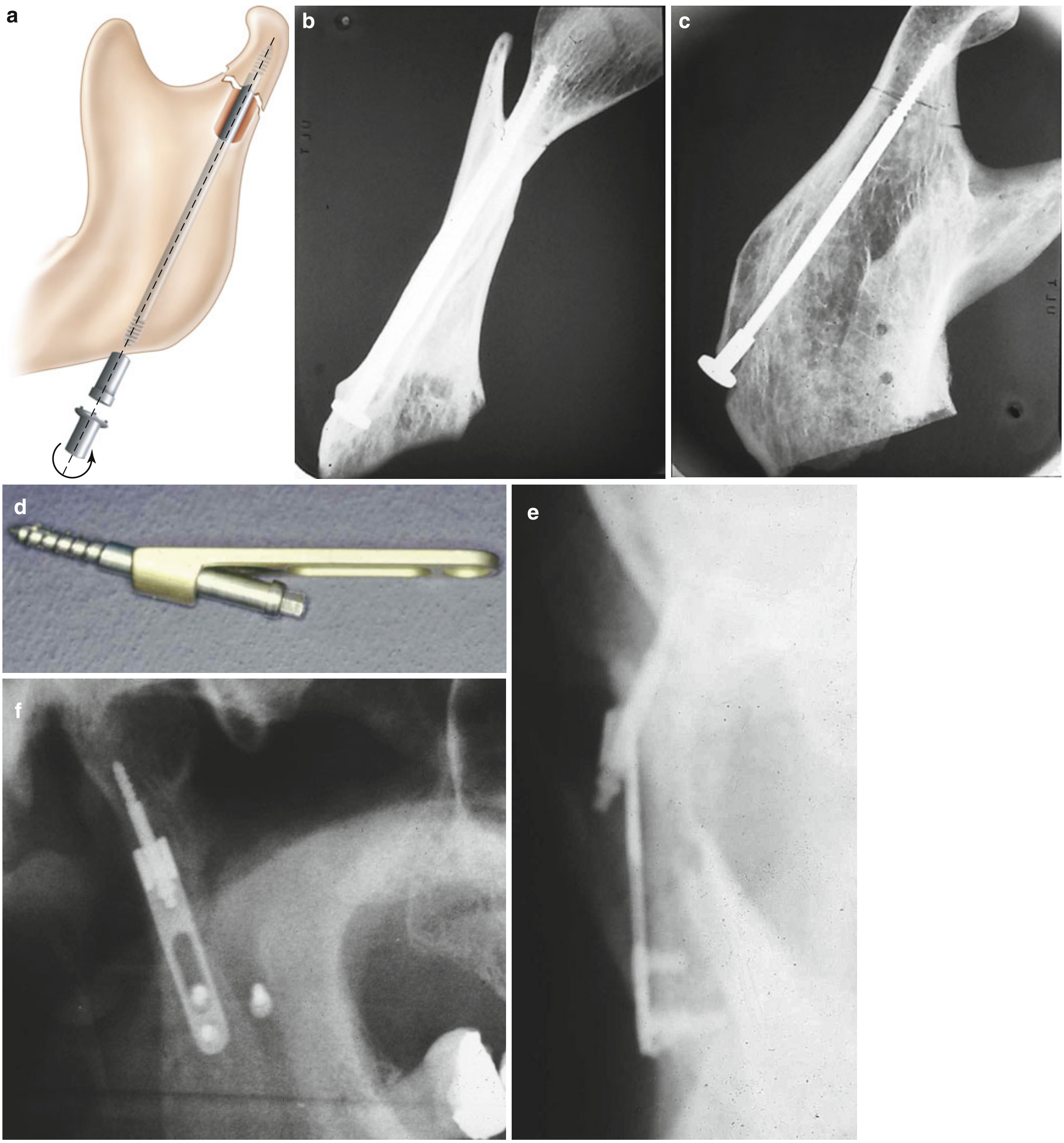

Fig. 6.122 Condylar lag screw. This technique is rarely performed today (**a**–**f**)

6.8 Comminuted and Complex Mandibular Fractures

In many centers today, the overwhelming majority of low-energy mandibular fractures are managed using transoral miniplate synthesis and the techniques just described (see Fig. 6.123). Conceptually, this form of osteosynthesis using monocortical fixation is often referred to as “load sharing.” This means that following repair, a proportion of the functional loading across the fracture is carried by the bones themselves and not entirely by the plates and screws. Movement at the fracture therefore occurs. This in itself is not a bad thing; a small amount of loading across a fracture encourages “micromovement,” which itself encourages healing. It is only when a fracture is overloaded that this becomes a problem.

In contrast, higher energy injuries to the mandible can result in comminuted fractures in which load sharing is not possible. These are a difficult group of fractures to manage and are commonly associated with complications if inadequately repaired. A significant portion of the energy during impact is transferred through the surrounding soft tissues, also damaging them. Often the overlying skin is split. Therefore many of these fractures are open (previously termed “compound”) and contaminated. Not only is the vascularity compromised but multiple fragments, some very small, are difficult to stabilise without using an excessive numbers of plates (all of which themselves are foreign bodies). These small fragments are often difficult to manipulate and secure, while maintaining their soft tissue attachments. They are therefore at risk of becoming loose or devitalised later on. All this results in a high risk of fragment necrosis, sequestration, nonunion, infection and, in some cases, continuity defect. The key to successful management is therefore maintaining both adequate immobilisation of the fragments and sufficient vascularity, while also minimising contamination and preventing subsequent infection.

Traditionally, management of these fractures used closed techniques, thereby avoiding periosteal stripping and further devitalising the bone. However, these techniques do not guarantee adequate immobilisation of all the fragments, although clinically they do work well in selected cases. These techniques have been previously discussed (IMF and external fixation). More recently, a more aggressive approach of open reduction and rigid internal fixation has been advocated. A number of reports have argued that maintaining the periosteal attachment is not as important as stabilising the bony fragments. This is only possible if the fixation is rigid.

Two elements are essential for success:

- The fixation needs to be fully load-bearing and
- There must be absolute stability across the fracture

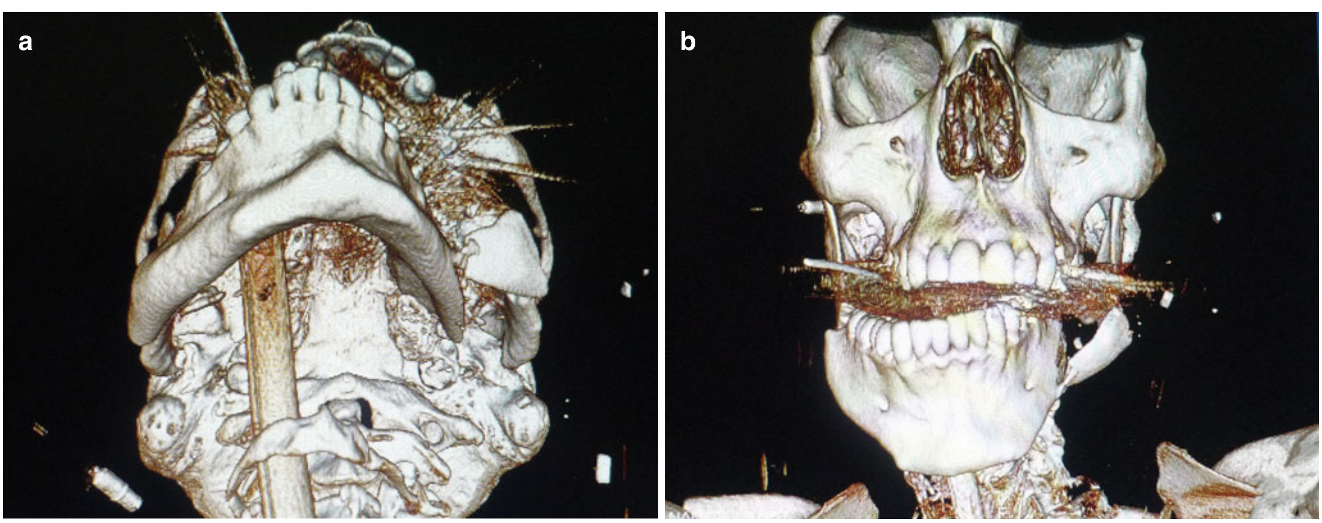

Fig. 6.123 Comminuted and complex mandibular fracture (**a**, **b**)

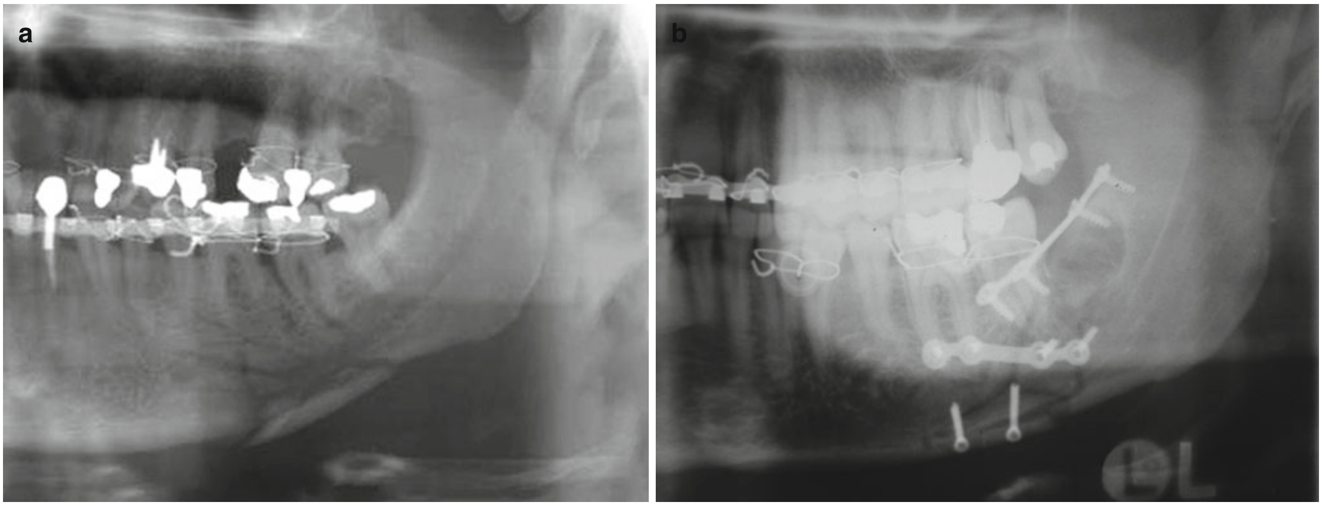

Fig. 6.124 Comminuted lower border fracture. In this case satisfactory repair was possible using a combination of adaptive miniplates and lag screws (**a**, **b**)

Table 6.9 Various classifications of pathological fractures

Nonspecific	Local	Systemic
Delayed presentation	Gross comminution	Osteoporosis
High-energy transfer	Bone loss	Osteogenesis imperfecta
High alcohol	Gunshot	Bisphosphonate use
Heavy smokers	Infection	Postradiotherapy
	Edentulous	
	Fragility	
	Pathological	
	Odontogenic cyst	
	Odontogenic tumour	
	Primary tumour	
	Secondary tumour	

Under these circumstances, small bone fragments can then be replaced and fixed as free bone grafts, with a good chance for rapid bone healing and a low rate of infection.

The choice of treatment therefore lies between maximising soft tissue attachments and vascularity (using IMF/external fixation) or maximising stability across the fragments (by load-bearing osteosynthesis). Unfortunately, both are not possible in the same patient, although some surgeons make a compromise by using smaller miniplates, with less periosteal dissection, supplemented with lag screws and IMF (*see* Fig. 6.124).

Whichever approach is undertaken, there will always be a risk of infection, non-union, or malunion. With very high impact energies, such as blast injuries, some surgeons recommend delaying treatment at least several days or longer. This enables nonvital tissue to demarcate itself, which can then be excised as part of the definitive repair. Once the airway is secure and haemorrhage controlled, these injuries are not life-threatening and can wait while further imaging (notably CT) defines the extent of the fracture. Temporary IMF or external fixation can be used in the interim.

Any fracture that cannot be treated with load-sharing principles may be referred to as complex. This is often the case with pathological fractures, which are additionally complex by virtue of their predisposing pathology. Various classifications of pathological fractures exist (*see* Table 6.9).

In a sense these injuries simply represent one end of the normal distribution of complexity. Compare a simple mandibular fracture involving the left angle and right parasymphysis with a complex fracture involving the entire right-hand side of the mandible (*see* Figs. 6.125 and 6.126).

Due to the high injuring mechanism frequently associated, these latter fractures are commonly associated with injuries across the whole craniofacial complex. Management of these fractures is illustrated in the following cases.

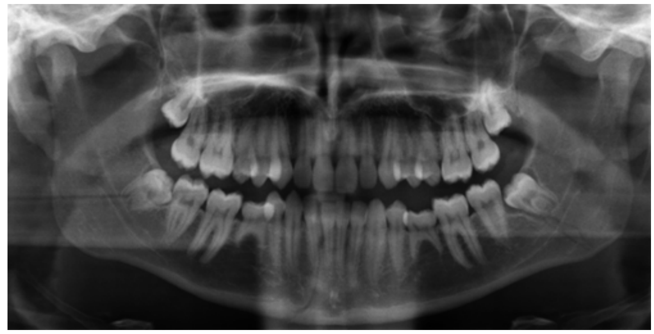

Fig. 6.125 “Simple” fracture

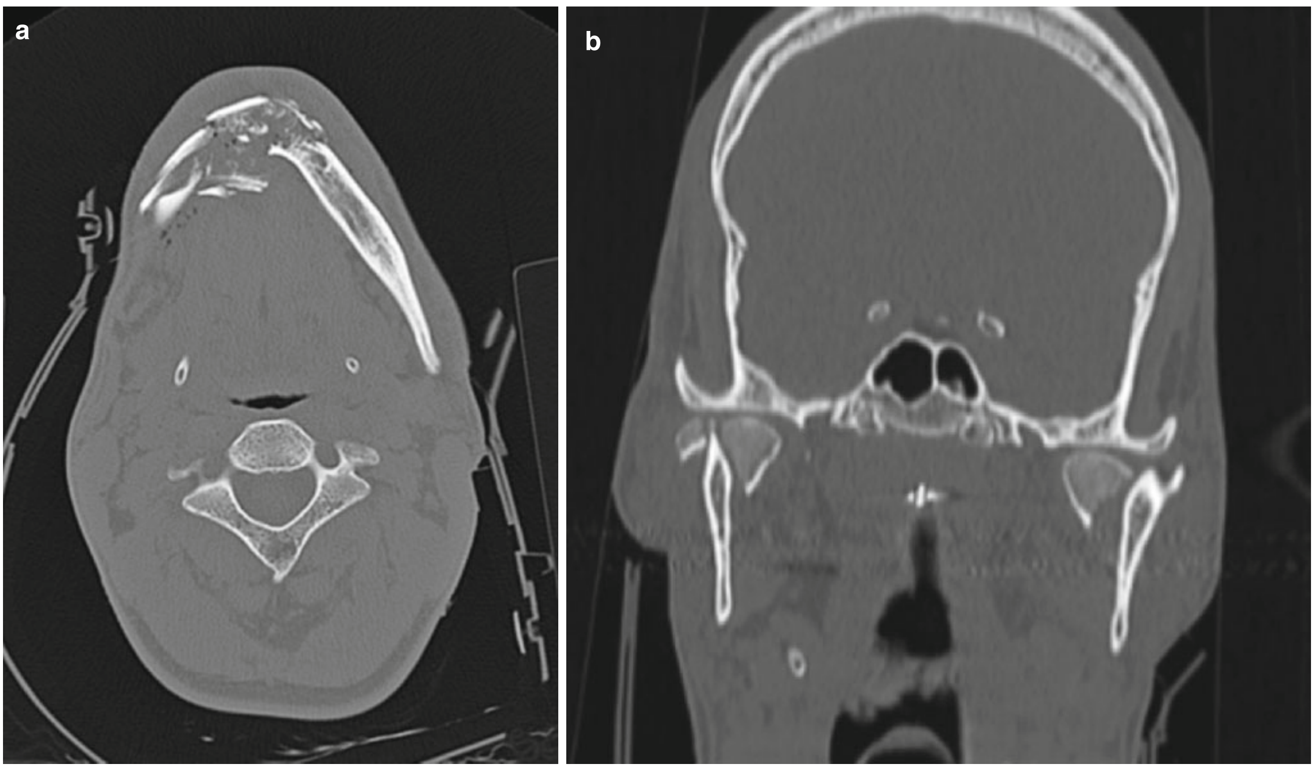

Fig. 6.126 “Complex” fracture (**a**, **b**)

Case 1

The mechanism of injury involved a fall from 40 ft. There were associated lower limb and lumbar spine injuries (see Figs. 6.127, 6.128 and 6.129).

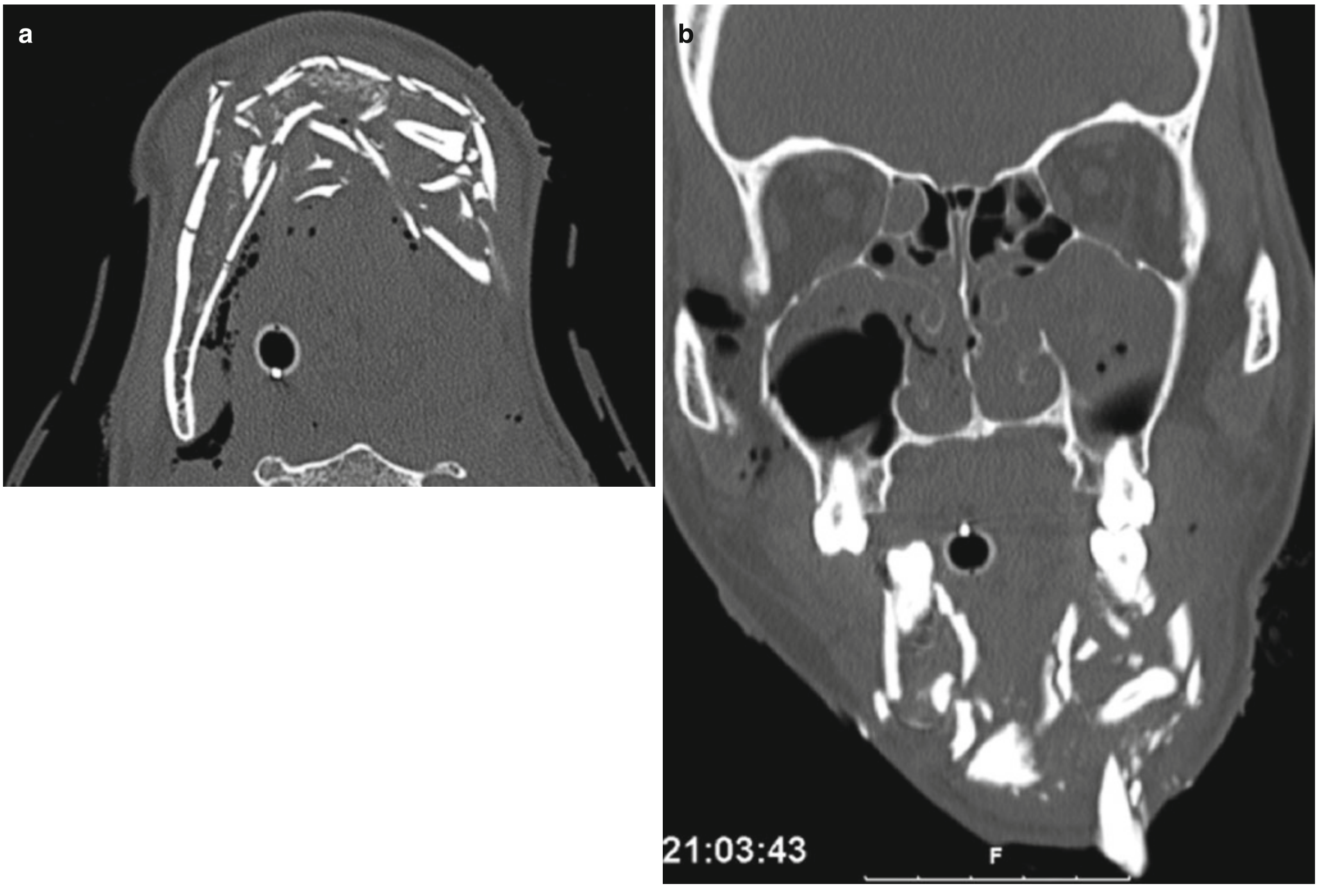

Fig. 6.127 See text for description (**a**, **b**)

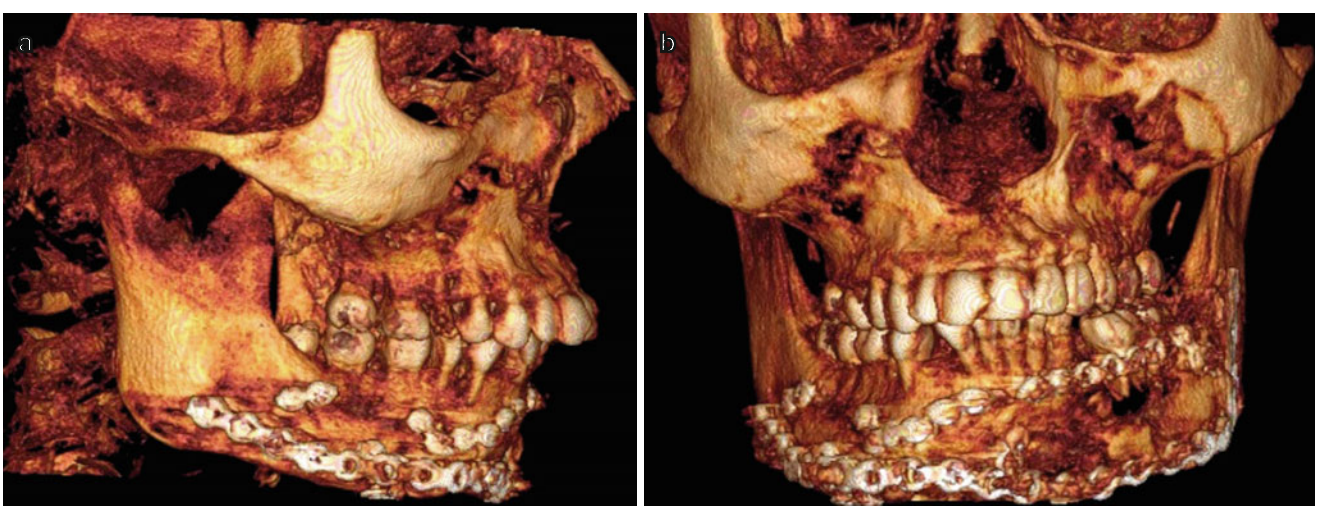

Fig. 6.128 Postoperative repair (**a**, **b**)

Fig. 6.129 Postoperative appearances (**a**–**c**)

Axial CT scanning demonstrated gross comminution across the mandible (note the lateral displacement of the endotracheal tube). In addition, the swelling also displaced a premolar within the fracture complex, lending insight into the compressive nature of the mechanism of injury. The coronal CT demonstrated the intense fragmentation and numerous displaced teeth. Bone was seen extruding through a soft tissue laceration. Coexisting midface fractures were also present.

Management of the mandible in this case is outlined in Table 6.10.

Table 6.10 Management of Case 1

Surgical airway
Arrest of haemorrhage
Debridement of fracture (first look); identification and removal of displaced teeth
ITU/resuscitation
Delayed repair involving Extension of soft tissue laceration Miniplate fixation to major tooth bearing fragment Reconstruction plate to mandible in teeth in occlusion
Closed reduction of nasal bone, maxillary fracture, and left zygoma

This case illustrates a number of important planning principles.

- Partially denuded dentoalveolar segments remain a considerable diagnostic, prognostic, and treatment dilemma.
- A balance must be drawn between the structural advantage of stabilising teeth (to provide vertical and transverse dimensional support), against the risk of loss of vitality.

Case 2

This patient sustained a high-velocity wound from an AK47 rifle during a bank robbery (see Figs. 6.130, 6.131, 6.132 and Table 6.11).

Fig. 6.130 Clinical examination (**a**, **b**) and three-dimensional reformat (**c**) demonstrated loss of the anterior portion of mandible together with the lower lip, ventral floor of mouth, chin, and anterior neck. Maxillary tissue loss was confined to the dentoalveolar segments. Following airway stabilisation and resuscitation, the patient was subsequently transferred for reconstruction a few days later. Management is outlined in Table 6.11 (Permission form Professor Iain Hutchison and Andrew Dawood)

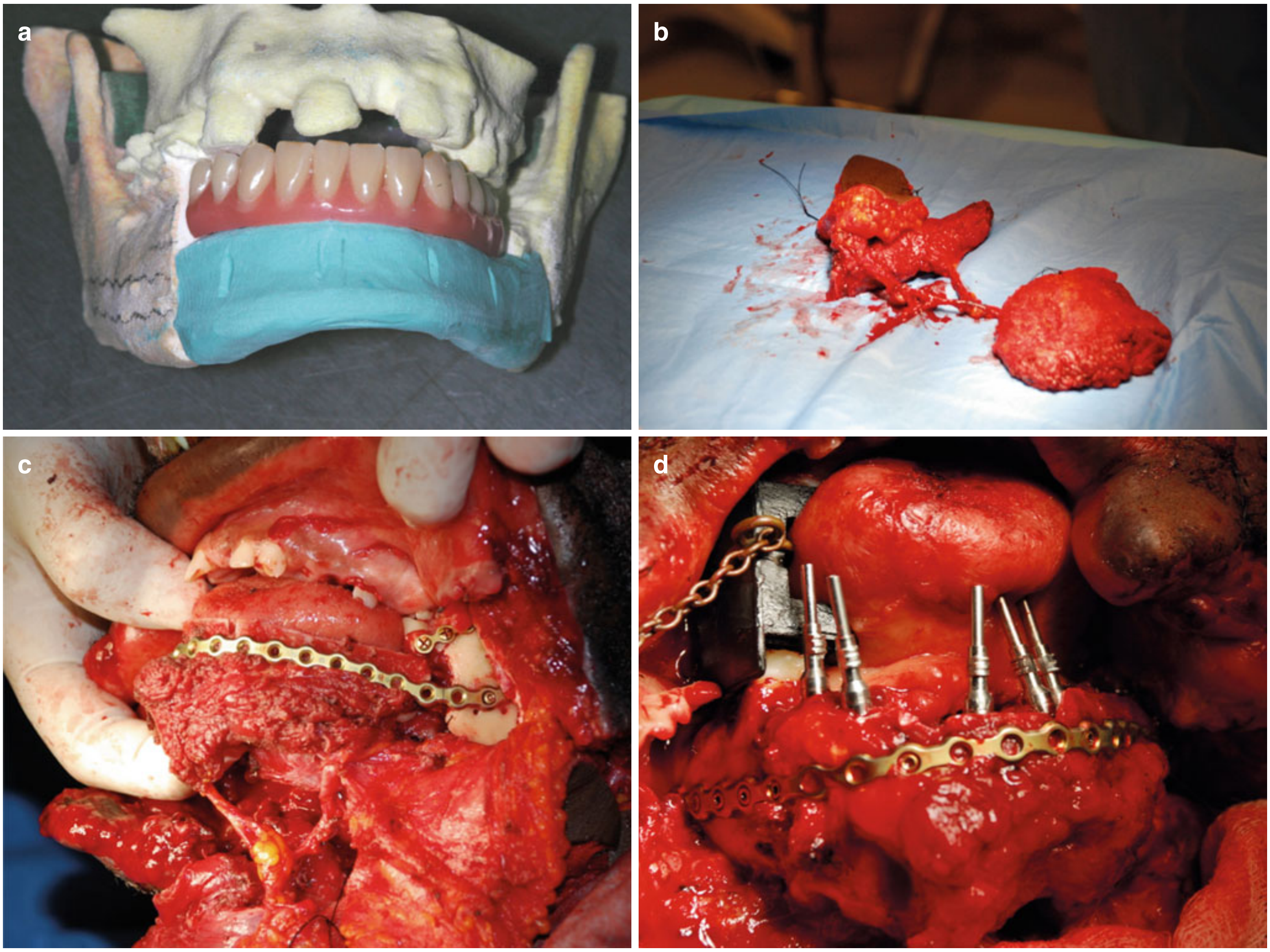

Fig. 6.131 Avulsion defect and high-energy injury (**a**–**d**). See text for treatment planning and repair

Fig. 6.132 Postoperative appearance

Clinical examination and three-dimensional reformat demonstrated loss of the anterior portion of mandible together with the lower lip, ventral floor of mouth, chin, and anterior neck. Maxillary tissue loss was confined to the dentoalveolar segments. Following airway stabilisation and resuscitation the patient was subsequently transferred for reconstruction a few days later. Management is outlined in Table 6.10.

Table 6.11 Management of Case 2

Debridement
Preoperative fixed prosthesis fabrication
Free tissue transfer of composite scapular free flap including parascapular skin, scapula bone, and latissimus dorsi muscle
Intraoperative dental implant fabrication
Maxillary implant reconstruction

6.9 Coronoid Fracture

This is an uncommon fracture, comprising around 1 % of all mandibular fractures. Often it arises as an avulsion-type fracture, due to the pull of the attached temporalis muscle tendon. However, impacts directly onto the side of the face can result in these fractures. When the teeth are in occlusion, the tip of the coronoid is usually medial to the zygomatic arch and blows here can sometimes result in fractures to both bones. Management of isolated coronoid fractures is usually nonsurgical. When the zygomatic arch has also been fractured it is commonly taught that there is a risk of ankylosis between the two healing sites and that surgical treatment is necessary. Being such a rare fracture, the evidence for this is more anecdotal, although it seems logical. Coronoidectomy of the fracture fragment is a relatively easy procedure, if the fractured tip has not retracted upwards. If no surgery is undertaken, jaw exercises (chewing gum is useful for this), may prevent ankylosis.

6.10 The Atrophic Mandible

Fractures of the severely atrophic edentulous mandible can be difficult to manage. Once teeth are lost, progressive resorption of the bone occurs. This is accelerated when the overlying mucosa is loaded with a denture. Because there are only a few or no teeth to absorb some of the energy of impact, these fractures are often significantly displaced.

Greater understanding of bone healing and fixation techniques has now resulted in better outcomes. With increasing age, there is decreased vascularity in the mandible. In addition, the elderly mandible is often osteoporotic. Not surprisingly, this loss of vascularity and bone volume places the mandible at risk of fracture and a greater chance of developing nonunion, malunion, or infection. A direct relationship between the height of the bone in the fractured area and the incidence of complications has been reported (see Table 6.11).

A number of treatment options are available. These include:

1. No intervention and allow a fibrous union.
2. The use of the patient's dentures wired to the jaw, to splint the fracture (with or without IMF)
3. External fixation
4. Internal fixation using miniplates (both sub- and supraperiosteal)
5. Internal fixation using heavier reconstruction plates

Bone grafting has also been shown to be a useful adjunct, although this does carry the risk of additional morbidity at the donor site.

In minimally displaced fractures, a very soft diet and close follow-up may allow fibrous union to occur. Although not an anatomical union, this does avoid surgery in frail patients. The patient's dentures can then be relined for a better fit. Close follow-up is needed to ensure that the fracture ends do not ulcerate through the overlying mucosa. However, bilateral "bucket handle" fractures do tend to sag.

Closed reduction may be effective, although immobilising the fracture with the patient's denture can be difficult. If the patient does not have a denture, occlusal splints (Gunning) can be fabricated. Longer periods of IMF may be necessary to allow for healing (*see* Fig. 6.133).

External fixation can be used in patients where there are major concerns about healing, or where the bone is comminuted.

Open reduction has been reported to give good outcomes. Fixation varies from large rigid reconstruction plates to smaller semirigid miniplates. In some cases, simultaneous bone grafting may be undertaken, although there is little evidence in the literature to demonstrate that this provides major benefit. Bone grafts are believed to increase the osteogenic potential of fracture site. Rib, iliac crest, and tibia have all been used (*see* Fig. 6.134–6.137).

Table 6.12 Classification of the atrophic edentulous mandible

Type 1 (16–20 mm)
Type 2 (11–15 mm)
Type 3 (10 mm or less)
Fibrous union or nonunion are more likely to occur when the height of the mandible is less than 10 mm
Above 20-mm conventional miniplate fixation is usually effective
Heights of 30 mm or more can be regarded as nonatrophic

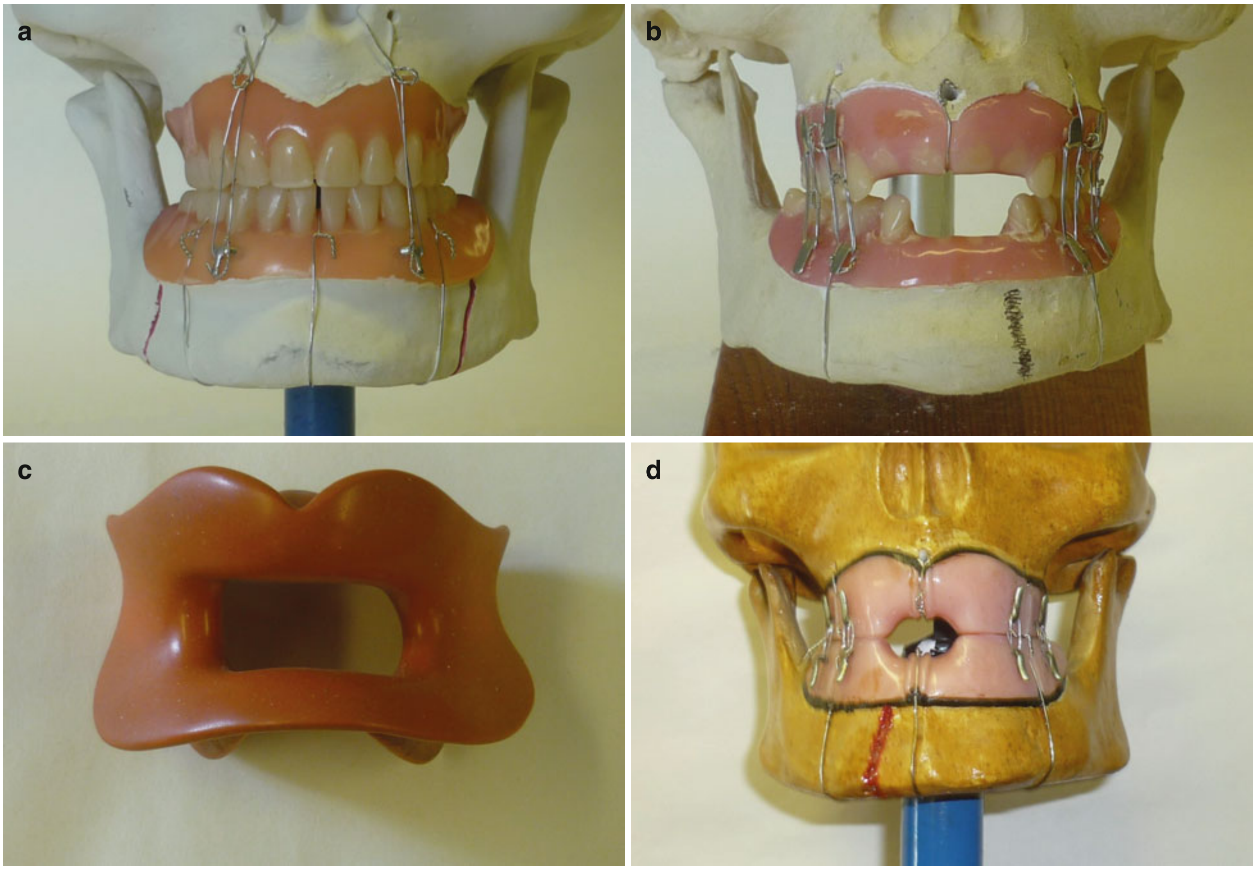

Fig. 6.133 Patients' dentures or gunning splints can be used to stabilise the mandible (**a**–**d**). These need to be secured to the patient, so still require a general anaesthetic

Case 1

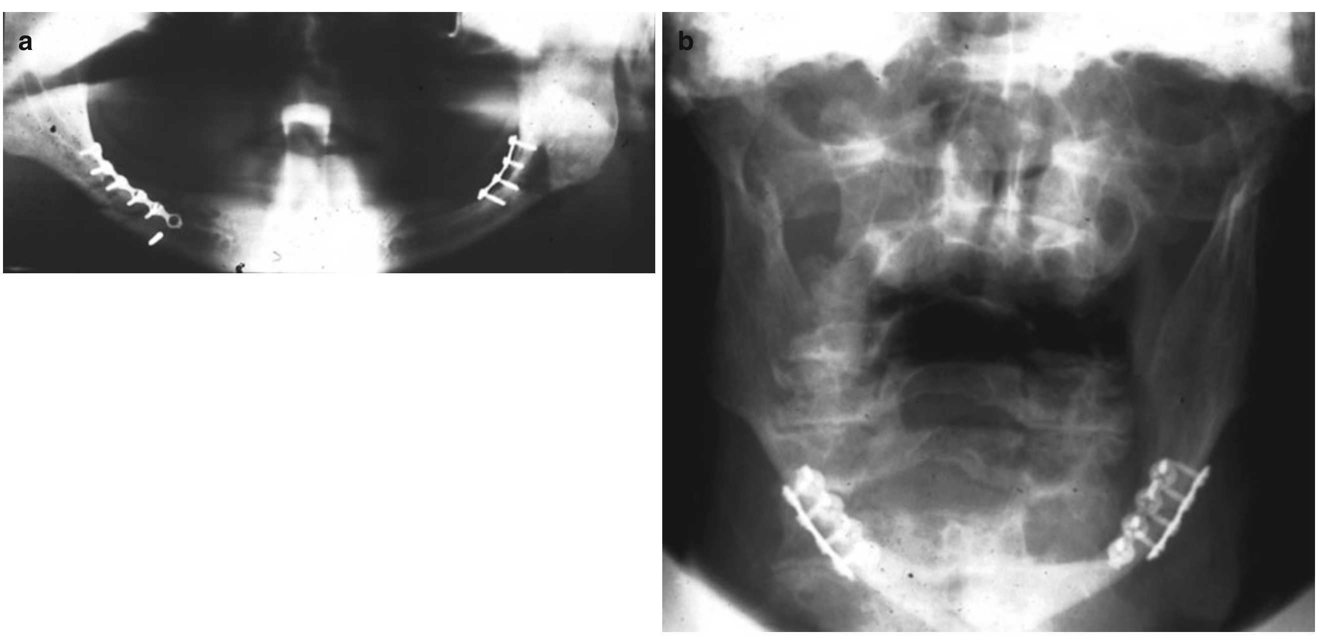

Fig. 6.134 Upper border fixation (**a**, **b**)

Case 2

Fig. 6.135 Extremely atrophic lower jaw with bilateral fractures (**a**–**c**)

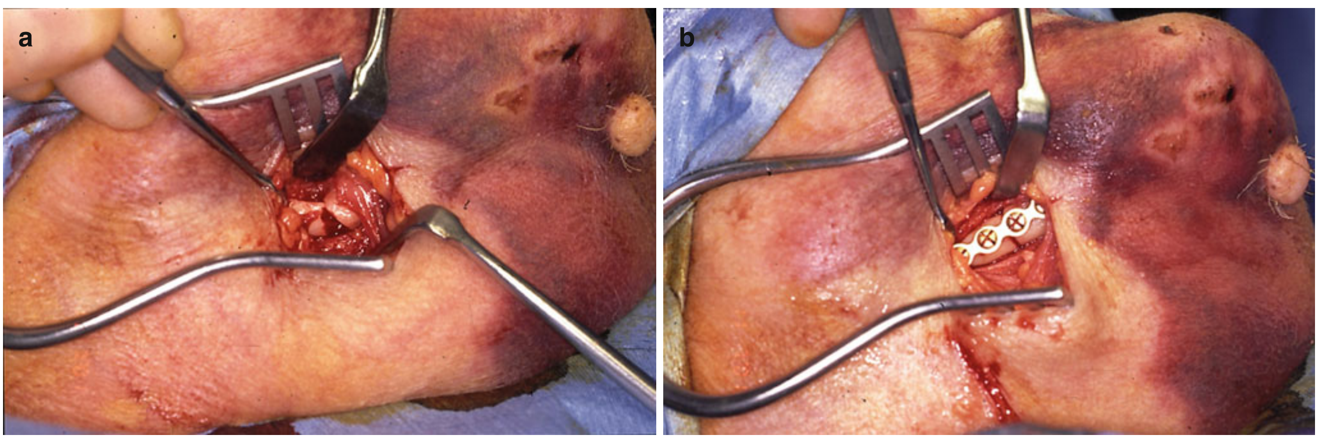

Fig. 6.136 Exposure of the thicker bone (**a**). This was plated with a 2.3-mm plate and bicortical screws (**b**)

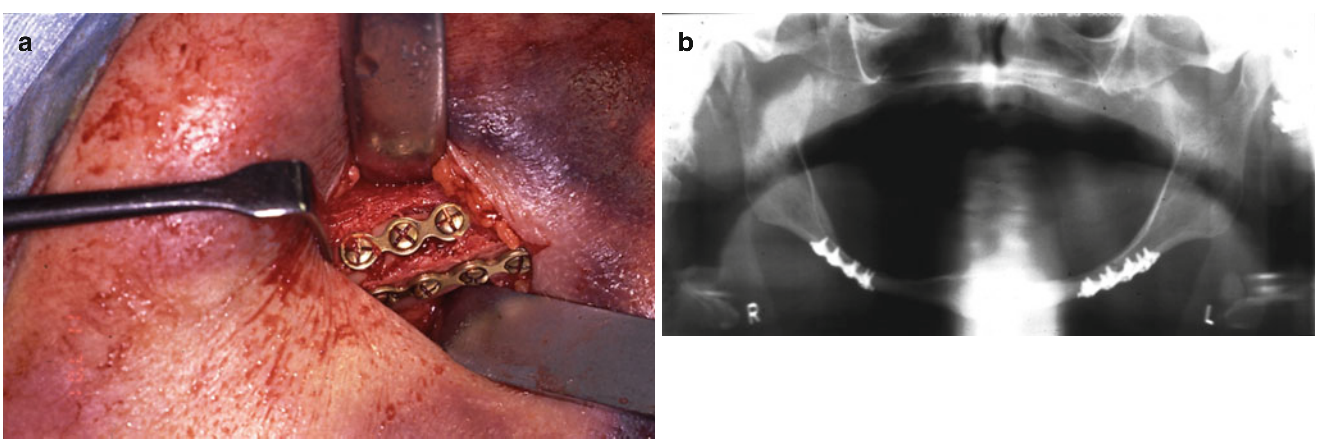

Fig. 6.137 The thinner side required rib grafting (**a**, **b**)

Case 3

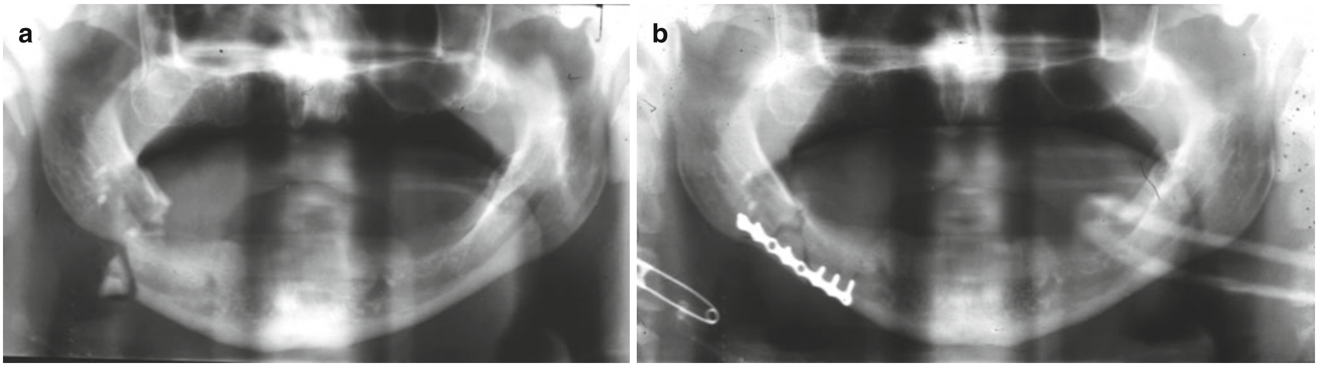

Fig. 6.138 Load-bearing osteosynthesis was required due to the comminution (**a**, **b**)

Case 4

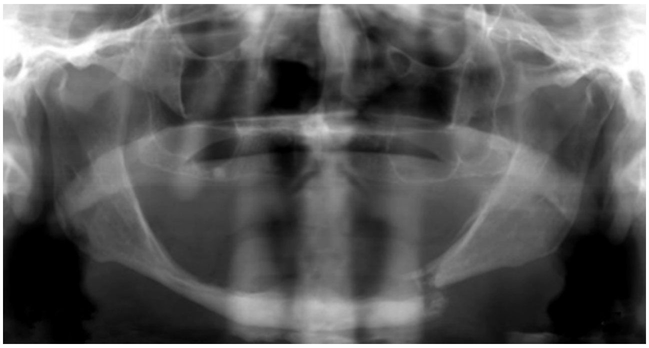

Fig. 6.139 How would you manage this?

The best way to manage these difficult fractures is still not known and the literature can be confusing. The 2007 Cochrane database review on this subject found that there was inadequate evidence to show better outcomes with any single approach over the other alternatives. Treatment is therefore based on the surgeon's experience and must be considered on a case-by-case basis (see Fig. 6.139). Close follow-up is advised.

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7 Fractures of the Middle Third of the Facial Skeleton

Michael Perry and Simon Holmes

The middle third of the facial skeleton is a complex anatomical region that can be considered as being composed of several distinct areas. Injuries to each site will have their own structural, aesthetic, and functional characteristics, as well as their own surgical challenges. Although the term "middle third" is commonly used to denote LeFort fractures, injuries to this region are often much more widespread and complex.

The term "midface" is often used to refer collectively to those structures situated between the skull base and the occlusal plane. "Middle third fractures," as they are also known, therefore overlap with fractures of the nose, nasoorbitoethmoid (NOE) region, and zygoma. They may also extend upwards, into the anterior cranial fossa. The bones of the midface are important in maintaining the functions of the oral cavity, nasal cavity, and orbits (see Fig. 7.1). Not surprisingly, injuries here also have significant cosmetic implications. Fractures of the midface tend to result from high-energy impacts and can therefore be both life-threatening as well as disfiguring.

Fig. 7.1 The term "midface" is often used to refer collectively to those structures situated between the skull base and the occlusal plane. "Middle third fractures", as they are also know, therefore overlap with fractures of the nose, nasoethmoid region and zygoma

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7.1 Applied Anatomy

The midface is a complex structure composed of a number of bones (see Table 7.1). Many of these are extremely thin.

The two maxillary bones are joined in the midline to form the bulk of the middle third of the face. They support the teeth and form the roof of the oral cavity. They also form the floor and part of the lateral wall of the nasal cavity, contain the maxillary sinus (antrum), and contribute to the medial part of the infraorbital rim and orbital floor.

An interesting and perhaps still unresolved question is, why do some animals have sinuses? A number of theories exist, but the question remains open to speculation. One interesting suggestion is that throughout man's evolution, the facial skeleton has evolved into a "crumple zone," functioning much like the chassis of a car. This has resulted in its capacity to absorb impact energy, thereby protecting the brain and conferring a survival advantage. According to Wolff's law, healthy bone remodels in response to functional stresses placed across it. Within the facial skeleton, most of these stresses are related to biting and chewing forces. Where bone is not needed, it is resorbed. Furthermore, the midface also supports several important organs (the eyes and upper respiratory/olfactory tract) within bony cavities.

Consequently in adults, the midface can be conceptually thought of as being composed of a series of vertical and horizontal bony struts or "buttresses," between which the sinuses, eyes, and part of the upper respiratory tract lie. Joining these buttresses together is "wafer-thin" bone, to which the soft tissues of the face are attached.

This arrangement defines the three-dimensional shape of the face. Although the buttresses are capable of resisting vertically directed biting forces (which can be considerable), they are less resistant to forces directed horizontally (a significant vector in most impacts). Therefore, they collapse. In the same way that the chassis of a car is designed to collapse on impact, thereby absorbing the kinetic energy (protecting the driver), when a force is applied to the face the underlying bones collapse, absorbing the kinetic energy and protecting the brain. Although this has an obvious survival advantage, this postulated protective mechanism can result in significant displacement of the bones. Similarly, condylar fractures may afford a degree of protection to the brain stem and upper cervical cord (passing through the rigid foramen magnum), following a blow to the chin.

In the treatment planning of the injured midface, attention to these buttresses is therefore particularly important (see Table 7.2 and Figs. 7.2, 7.3 and 7.4). Anatomical reduction is essential if precise three-dimensional reestablishment facial height, width, and projection is to be achieved. Inability to achieve this can result in both functional and cosmetic deformity. Attention to the nasal septum is also an important part of the treatment plan. Not only is this crucial in the development of the growing midface, but it is an important element in maintaining nasal projection and patency. Nasal injuries are discussed elsewhere.

The midface is suspended from the thicker skull base, which inclines downwards and backwards, at approximately 45° to the horizontal plane. High-energy impacts can therefore result in the middle third being displaced along the cranial base and forced downwards and backwards along this plane (see Fig. 7.5). The upper posterior teeth impact on the lower ones and prop open the bite. Clinically this results in an elongated face and deranged bite (anterior open bite). In severe cases, there may be significant swelling, severe bleeding, and airway compromise (particularly in the supine patient).

Table 7.1 Bones of the midface

2 Maxillae
2 Palatine bones
2 Lacrimal bones
2 Zygomatic processes of the temporal bones
Sphenoid pterygoid plates
2 Zygomas
2 Nasal bones
2 Inferior conchae
Ethmoid vomer

Table 7.2 Anatomy of the buttresses

The midface has three paired pillars or "buttresses" that take the load of any vertically applied force (i.e., biting).
Anterior: passes up alongside the piriform fossa to the frontonasal process (articulation of the maxilla with the frontal bone)
Middle: formed by the zygoma articulating with the maxilla anteriorly and inferiorly and the frontal bone above
Posterior: the pterygoid plates that attach the maxilla to the base of skull

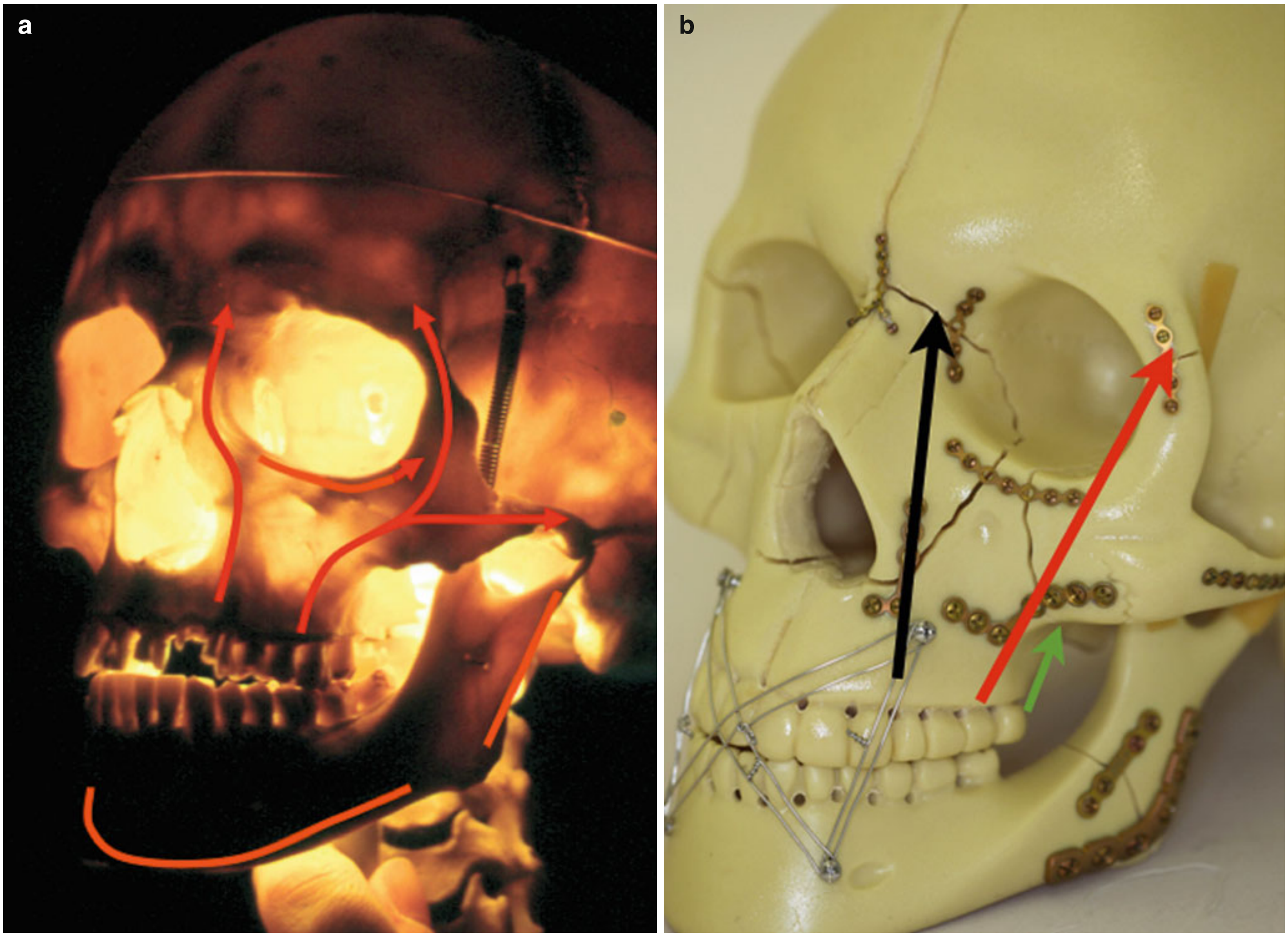

Fig. 7.2 A transilluminated dried skull showing "struts" of thick bone spanned by much thinner sheets of bone (**a**). The struts or "buttresses" are arranged to resist functional forces. Three paired buttresses are usually described anterior buttress - piriform appertures (*black*) middle buttress - zygomaticomaxillary buttress (*red*) posterior buttress - ptrerygoid buttress (*green*) (**b**). Curved red lines are along strategically thick areas ob bone

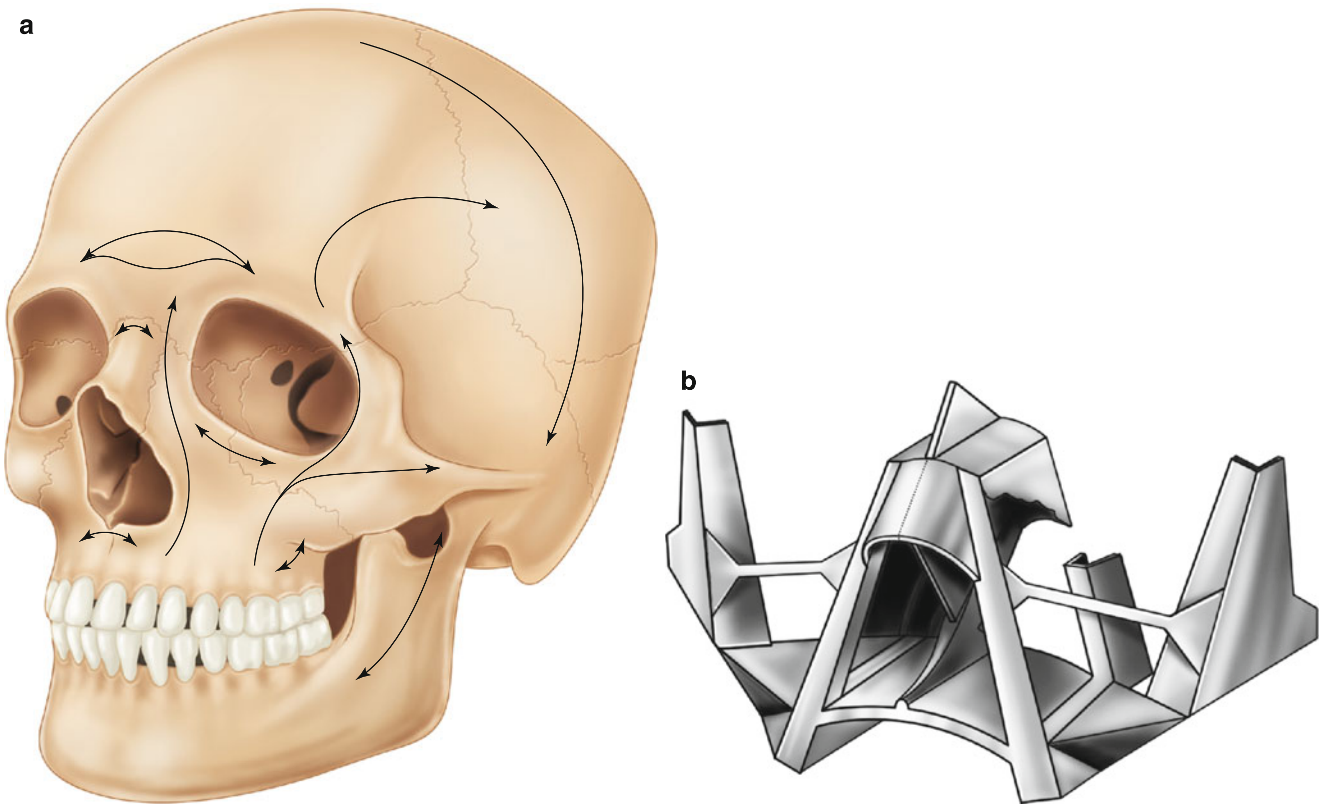

Fig. 7.3 Schematic arrangement of the various buttresses (**a**, **b**)

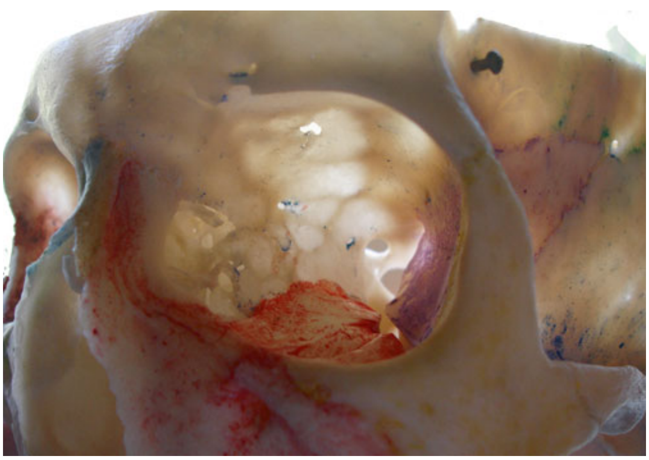

Fig. 7.4 Transillumination of the ethmoid sinuses and anterior skull base. In some parts of the face, the bones can be extremely thin

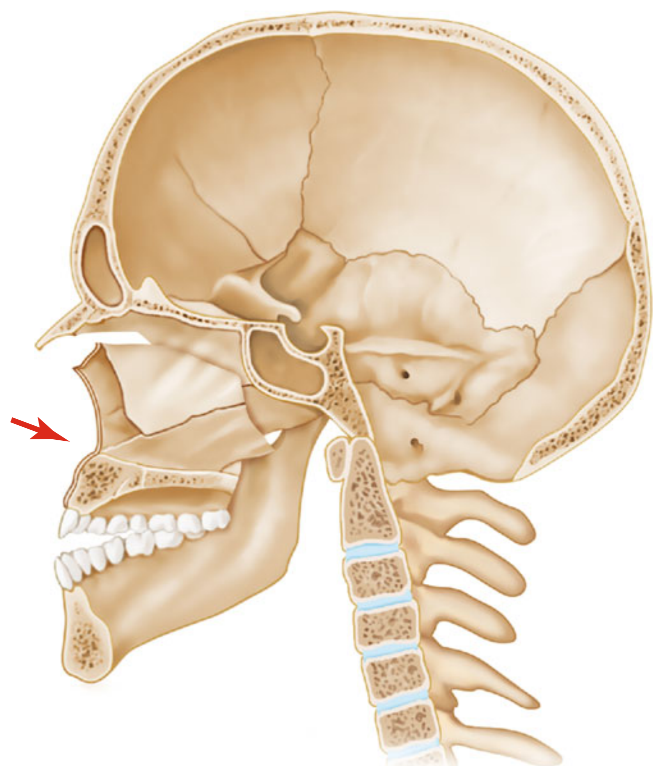

Fig. 7.5 Collapse of the midface following impact. This can shear off the thicker skull base, impacting posteriorly. *Arrow* indicate the direction of force (*Red*)

7.2 Le Fort Fractures

The Le Fort classification of midfacial fractures has endured although it is compromised by its simplicity (see Table 7.3). Its clinical usefulness is somewhat limited today due to the complexity of fractures which are now seen following higher energy impacts. "Pure" Le Fort fractures are not commonly seen. Nevertheless, this classification does give an indication of the amount of trauma sustained and clues to the possibility of associated injuries (notably cervical spine, brain, and ocular).

> Both Le Fort II and III fractures involve the orbit (risk to the eyes) and potentially involve the anterior cranial fossa (associated head injury/cerebrospinal fluid [CSF] leakage) (see Figs. 7.6, 7.7 and 7.8).

Table 7.3 Le Fort fracture classification

LeFort I ("**Low level**")
This fracture lies horizontally just above the nasal floor and sinuses, passing posterolaterally from the piriform aperture to below the zygomatic buttress. It also passes along the lower third of the nasal septum and lateral walls of the nose to join the lateral fracture at the lower third of the pterygoid plates. This is essentially separation of the palate and dentoalveolar bone (think of an upper complete denture)
LeFort II ("**Pyramidal**").
This fracture passes laterally from the nasal bones across the frontal processes of the maxillae into the medial orbital walls and lacrimal bones. It then passes through the anteromedial part of the orbital floor crossing the inferior orbital margin close to the infraorbital foramen. The fracture then passes downward and backwards across the lateral wall of the antrum to pass through the middle of the pterygoid plates. In the nasal cavity, the fracture passes through the nasal septum and may involve the cribriform plate.
LeFort III ("**High transverse**" or "**craniofacial dysjunction**")
This fracture passes from the frontonasal suture at the midline backwards through the ethmoid bone involving the cribriform plate. Laterally it passes through the orbit below the optic foramen to the posterior end of the inferior orbital fissure. From here the fracture passes along the lateral wall of the orbit to the frontozygomatic process. Posteriorly it crosses the pterygo-maxillary fissure to separate the base of the skull from the pterygoids. Essentially this separates the entire facial skeleton from the skull base.
These fractures often occur in various combinations on one or both sides. They are also frequently associated with other fractures of the midface (e.g., zygoma, naso-orbitoethmoid)

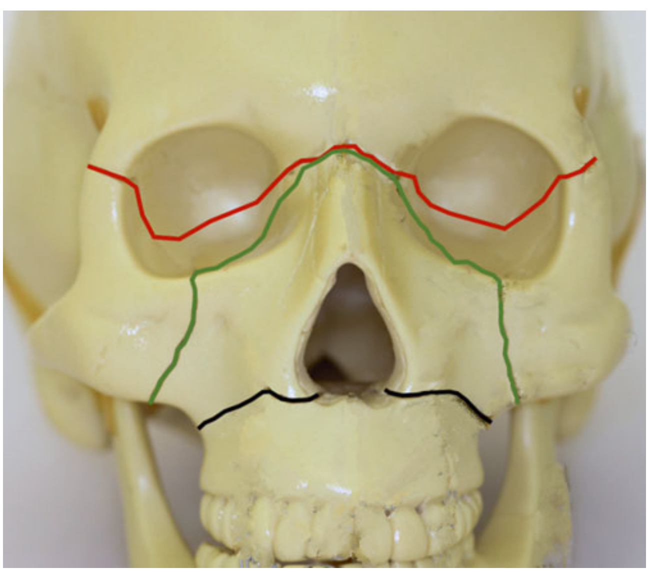

Fig. 7.6 Le Fort fracture pattern. Le Fort I (*black line*), Le Fort II (*green line*), and Le Fort III (*red line*). See Table 7.3 for details

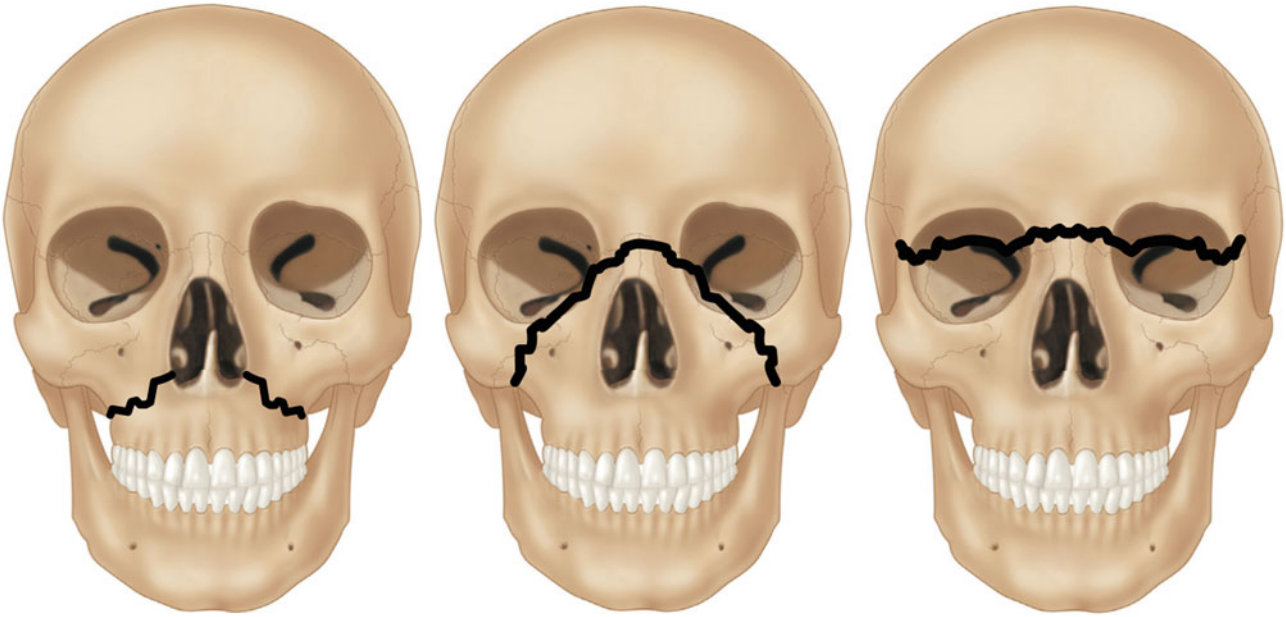

Fig. 7.7 Le Fort I (*left*), Le Fort II (*middle*), and Le Fort III (*right*) fractures disarticulated

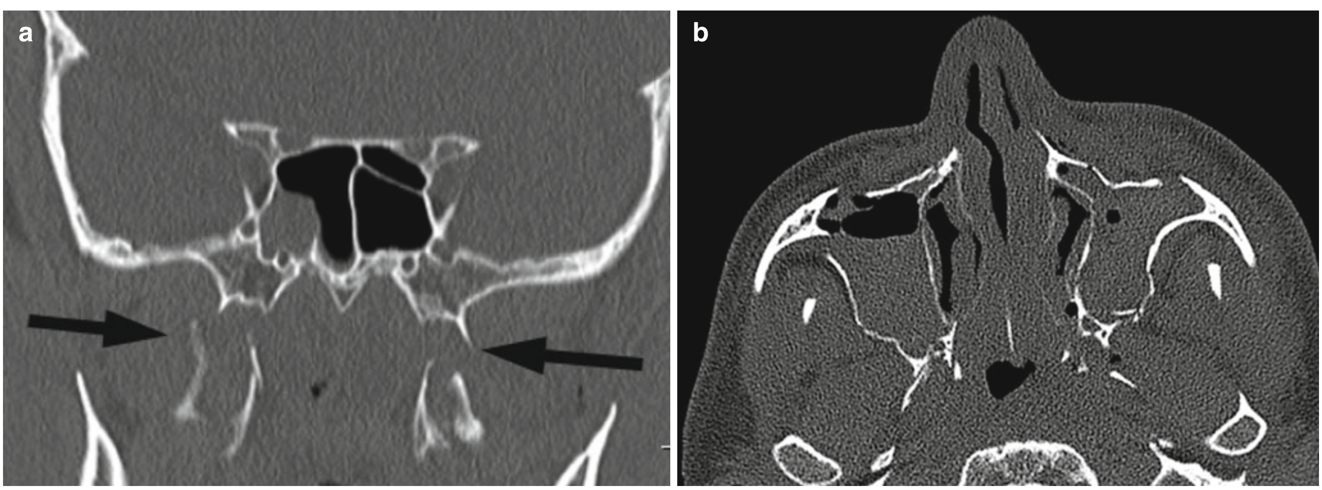

Fig. 7.8 Fracture of the pterygoid plates (*arrows*) seen on CT (**a**, **b**)

7.3 Clinical Examination

In theory, the level of a Le Fort fracture can be determined by a detailed clinical examination. However, in practice "pure" fractures are uncommon, as other fractures of the facial skeleton are often present. The clinical picture can therefore be a little uncertain. This is not a major concern nowadays, since such high energy injuries usually indicate the need for a computed tomography (CT) scan, which will ultimately define the fracture pattern. Nevertheless, a thorough examination is still required, not so much to decide which level the fracture is, but to assess for associated injuries. For the inexperienced, a simplified "check list" can be useful (see Table 7.4).

Abnormal mobility of the midface can be detected by grasping the anterior maxillary alveolus and gently rocking the maxilla. At the same time the other hand palpates the sites of suspected fractures (nasal bridge, inferior orbital margins, or frontozygomatic [FZ] sutures). Care is required if the neck has not been "cleared," and if concerns exist about the neck this part of the examination is best deferred. Alternatively, the head must be fully supported. If the teeth and palate move but the nasal bones are stable, a Le Fort I fracture is present (or it is a denture!). If the teeth, palate, and nasal bones move but the lateral orbital rims are stable, it is a Le Fort II fracture. If the whole midface feels unstable, it is probably a Le Fort III or some other complex fracture pattern.

Table 7.4 Clinical examination of midface injuries

Consider the following:
General features
ATLS/ABCs, notably progressive facial swelling, active bleeding, and cervical spine injuries
Neurosurgical
GCS
CSF rhinorrhoea (anterior cranial fossa #)/otorrhoea (middle cranial fossa #).
Complications of CSF leaks (meningitis or aerocele)
Ophthalmic
Visual acuity, signs of globe injury, pupil reaction to light
Enophthalmos/ocular dystopia
Diplopia
Maxillofacial
Abnormal mobility of the midface
Posterior oropharyngeal collapse
Anterior open bite
Apparent trismus—premature contacts in the molar region
Lengthening of the midface
Is the palate split?
"Dishfaced" deformity
Crepitus

Fig. 7.9 Clinical examination of the midface to determine Le Fort fracture level (see text for details)

7.3.1 Split Palate

This is an important part of the examination, yet something that can be easily overlooked. Midline or segmental splits of the palate occur following high-energy impacts and are often associated with widespread fractures of the midface. They rarely occur in isolation. If the palatal fragments are separated laterally they can sometimes act as a wedge, displacing the zygomatic buttresses laterally as well. If this is not recognised during repair, the buttresses may be plated in the wrong position, resulting in an increase in the transverse width of the face. Clues to a split palate include palatal bruising in the region of the greater palatine vessels (Guerin's sign), palatal mobility, or difficulty getting the patient into a satisfactory occlusion or intermaxillary fixation (IMF). If the mandible is fractured as well, a split palate can be easily missed. Achieving IMF is no safegaurd against its presence.

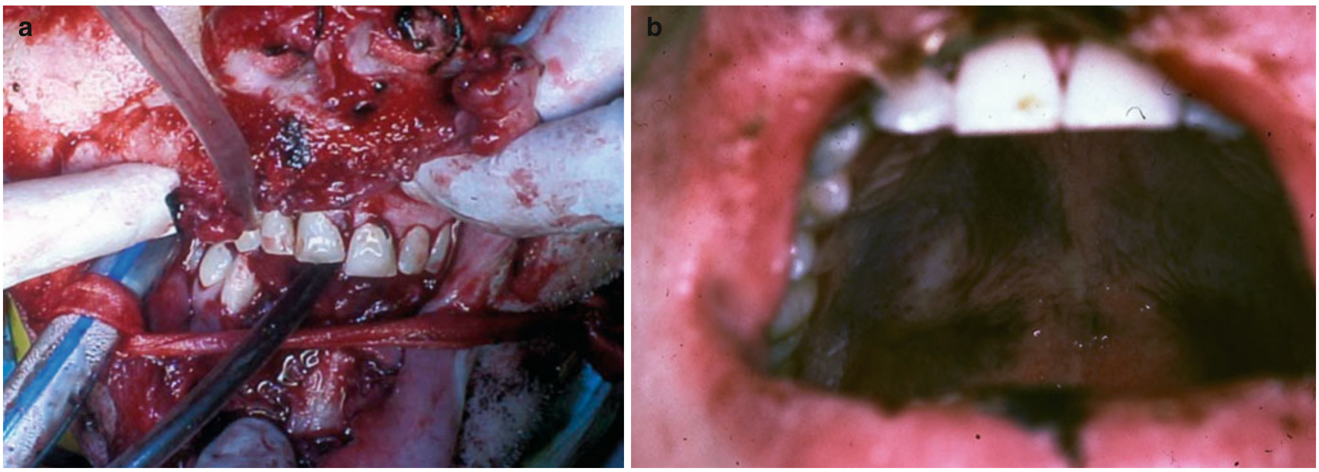

Fig. 7.10 Split palate (note differing levels of incisal edges) (**a**). Palatal bruising (Guerin's sign) (**b**)

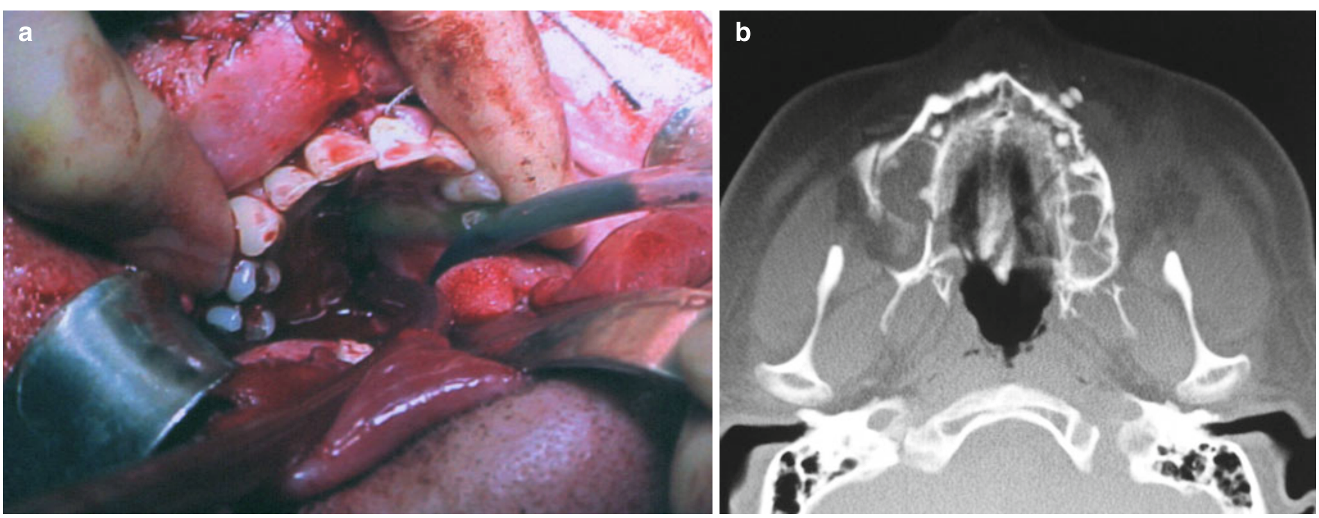

Fig. 7.11 Split palate (**a**) and CT appearances of segmental split of palate (**b**)

7.4 Investigations

Although plain films (occipitomentals [OMs]) may provide some useful information, patients with suspected midface fractures should ideally undergo CT scanning of the face (see Figs. 7.12, 7.13 and 7.14).

Although this is more accurate in defining the fractures, the true value of CT is in determining the presence of "deep" or occult injuries—those that may not be apparent on clinical examination (see Table 7.5). Patients may be neurologically impaired, very swollen, or require intubation, and clinical examination can therefore be difficult and unreliable. CT helps overcome some of these limitations.

It is important to remember that disimpaction and manipulation of the midface can potentially manipulate deep, mobile fragments around the skull base and optic nerve. Only by CT will these fractures be confirmed (or excluded) and the risks of manipulation recognised.

Remember also the possibility of inhaled foreign bodies (e.g., dental trauma), especially if there has been a history of loss of consciousness. A chest radiograph (CXR) and soft tissue views of the neck may be required. Magnetic resonance imaging may also be of value in the assessment of soft tissue injuries, particularly the cervical spine. CSF leakage may be difficult to confirm, especially in supine patients. "Tramlining" may sometimes be detected if blood-stained CSF leaks from the nose or ear and trickles down the face.

Fig. 7.12 Three-dimensional CT reformatting had greatly facilitated the diagnosis and planning of facial trauma

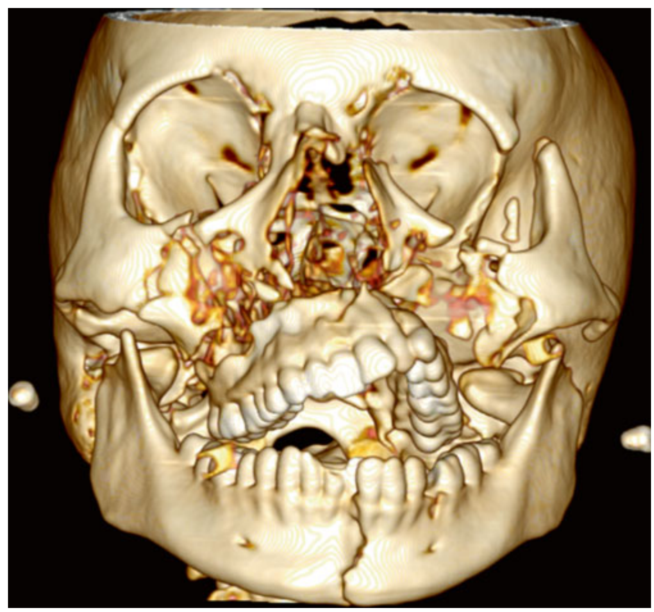

Fig. 7.13 Pure Le Fort fractures are rarely seen today. Their precise diagnosis can be very difficult, although this is not essential. The important part of CT assessment is to evaluate key sites (e.g., buttresses, skull base, orbital walls, palate, NOE region)

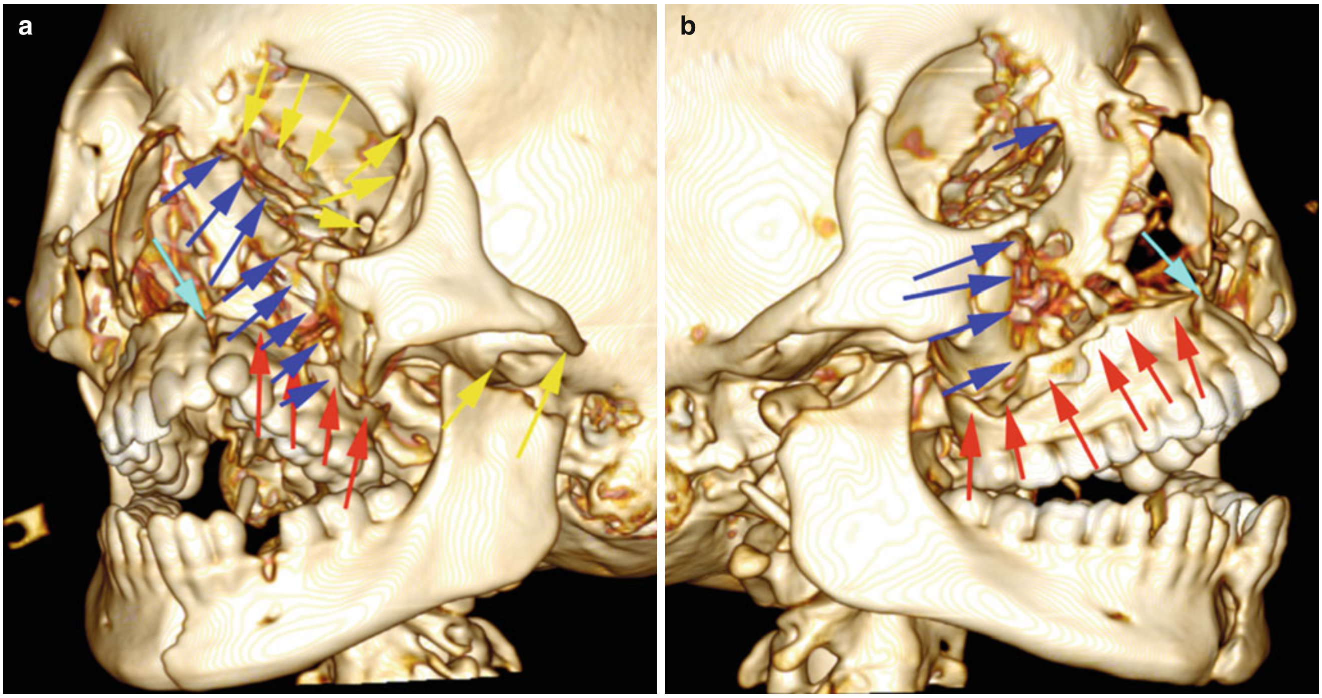

Fig. 7.14 Identifying fractures at various levels will help plan access and anticipate problems. In (**a**, **b**), *yellow arrows* indicate "high" or Le Fort III, *dark blue arrows* indicate Le Fort II, and *red arrows* indicate "low" or Le Fort I. The *light blue arrow* shows where the dental arch is split along the palate

Along the edges of this flow the blood clots, while the CSF washes away the central flow forming two parallel lines, hence the appearance of tramlines. Definitive tests include beta-2 transferrin measurements, although some surgeons simply make the assumption that CSF is present and treat the patient accordingly.

Table 7.5 CT scanning of the head, face, and neck

Consider the following:
Cervical spine injuries
Skull base fractures/intracranial air (CSF leaks)
Skull base fractures around vascular foramina (notably carotid tears)
Globe rupture/vitreous haemorrhage
Orbital apex fractures/optic nerve compression

7.5 Management

Most midface fractures follow high-energy impacts. These may be either localised or part of a wider pattern. Either way, initial assessment and management should follow Advanced Trauma Life Support principles, which are discussed elsewhere. This and other aspects of initial management are listed in Table 7.6.

> Be aware of the patient who keeps trying to sit up—they may be trying to clear the airway.

7.5.1 Surgical Repair

Meticulous attention to the buttresses is the key to successful repair of midface fractures. Not only are they important in establishing the three-dimensional shape of the face, but they are often the only bones thick enough to securely support plates and screws. If the buttresses are severely comminuted and cannot be repaired, bone grafting may be required.

Operative reduction and fixation of the midface is usually required in the majority of significantly displaced fractures. However, in patients in whom the maxilla is undisplaced and stable, or if the patient is unfit for surgery, nonoperative treatment may be appropriate. Although IMF can be used to "fine tune" minor dysocclusions (the mandible must be uninjured), this must be used with care. Prolonged vertical traction across the fracture (from an unsupported mandible) can result in a slow increase in facial height, if the maxilla is not fixed. This is essentially distraction osteogenesis of the fracture. If the maxilla is displaced in an edentulous patient, a new denture may be a simpler and safer option once the fracture has healed.

7.5.2 Maxillary Disimpaction

Disimpaction of the maxilla can sometimes be difficult, particularly if there has been a delay in treatment. When delay has occurred, the soft tissues begin to fibrose and contract. Ideally, therefore, disimpaction should be undertaken as soon as possible. Unfortunately, other injuries may take precedence resulting in unavoidable delay. When this occurs, disimpaction may require a considerable amount of force.

Prior to disimpaction it is important to review the patient's CT scans. Following high-energy injuries, not only may the bones of the midface be fractured, but some of these fractures can extend into the skull base. Forceful manipulation of the midface can then result in dural tears. The orbits should also be assessed, especially at the orbital apex where mobile fragments in this region can damage the optic nerve.

Maxillary disimpaction should be undertaken slowly and gradually and in a stepwise manner. Digital manipulation should first be attempted, as this is much safer than using heavy instrumentation. Sometimes a gentle rocking motion is enough to free the maxilla and re-establish the occlusion. While attempting to disimpact the maxilla, it is important to watch out for any CSF leakage, excessive bleeding, or proptosis, as these may indicate serious complications.

With heavily impacted midfaces, a more robust technique is required. Rowe's disimpaction forceps are a set of paired instruments specifically designed for this. Correct insertion is important. To use these effectively, both nasal airways have

Table 7.6 Initial management of midface fractures

Advanced trauma life support
Consider especially the possibility of head, cervical spine, ocular injuries, and foreign bodies in the airway
First aid (once patient is stabilised)
Control epistaxis as necessary (cautery/ligation/packs)
Globe protection (especially in the unconscious patient)
Wounds: remove dressings and assess wounds. Consider contamination, foreign bodies, and twisting of soft tissue pedicles. Ideally carefully explore under local anesthesia, clean and close, but if the patient will be going to theatre, this can be delayed. Place a few light "tacking" sutures.
Antibiotics: usually broad-spectrum intravenous. Many regimes exist.
Tetanus: ensure tetanus prophylaxis is up to date
Analgesia
Advise patient: "do not blow your nose"

to be sufficiently patent along their entire length. Therefore, examination of the nose and review of the CT scan is important before attempting to place these. If the septum is significantly buckled such that the forceps cannot be passed, it may sometimes be possible to partially reposition it to allow their passage. Be careful as this will usually result in a fair amount of bleeding. In such cases it is also important to look at the attachment of the septum to the cribriform plate.

Rowe's instruments come as a pair. Each device consists of a long relatively straight arm (which is passed along the nasal airway) and a more curved "Ω"-shaped arm, which is designed to pass into the mouth, over the teeth. The handles of each instrument are offset to the side, so there is a specific instrument for the right side and a specific instrument for the left side. When both instruments have been placed in situ, squeezing the handle allows each instrument to independently grasp the palate between the nasal and palatal mucosa. The instruments are passed in one time as shown. When both are in position, the two handles can be grasped together so that the two instruments work as one device. Disimpaction can then be attempted. This is done by a gentle rocking motion, side to side and up and down. Significant bleeding may occur (see Figs. 7.15–7.21).

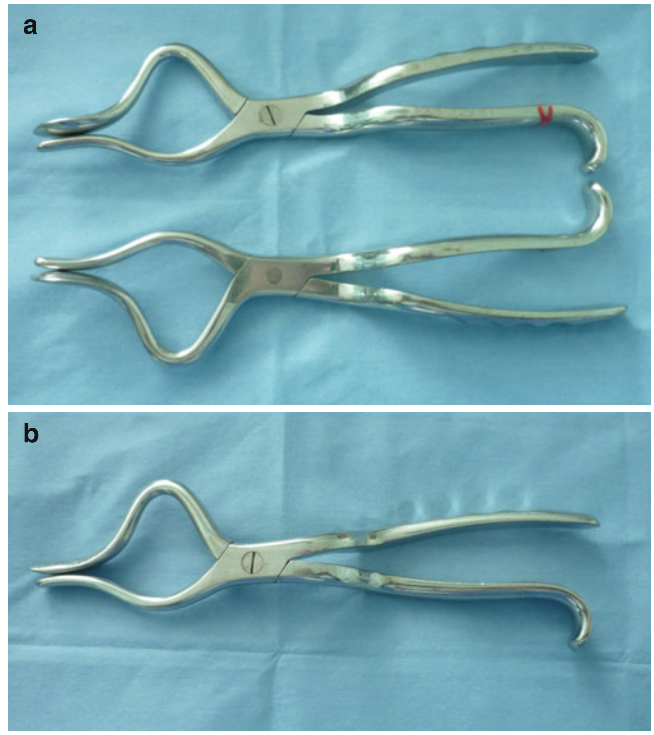

Fig. 7.15 Right (**a**) and left (**b**) Rowe's disimpaction forceps

Case 1

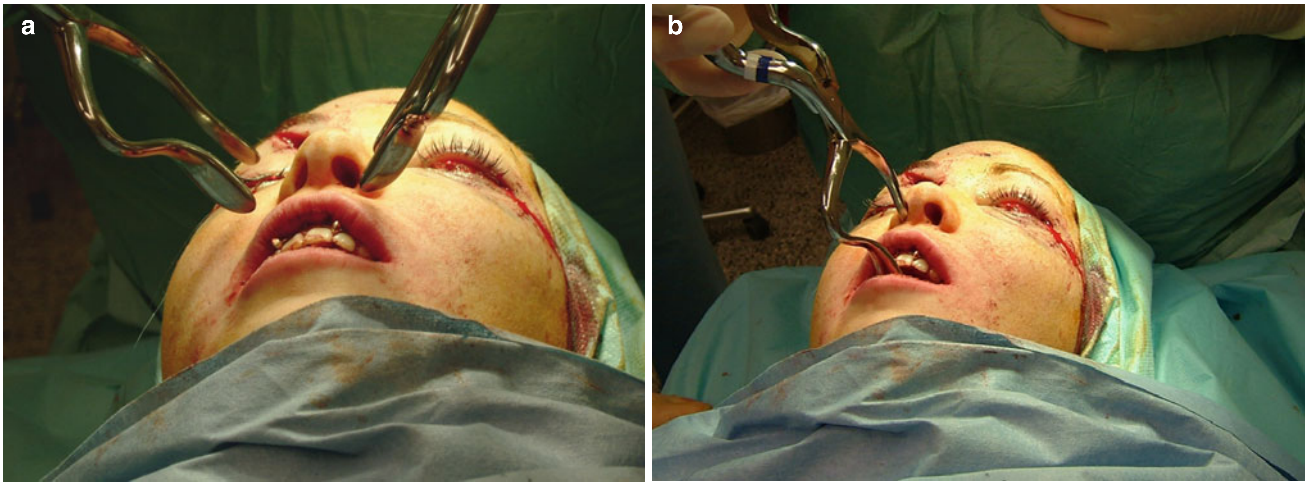

Fig. 7.16 Orientation (**a**) and initial insertion (**b**) of right instrument. Remember to check nasal patency before passing the instrument

Fig. 7.17 When fully seated, the blades grasp the palate between the nasal and palatal mucosa (**a**, **b**)

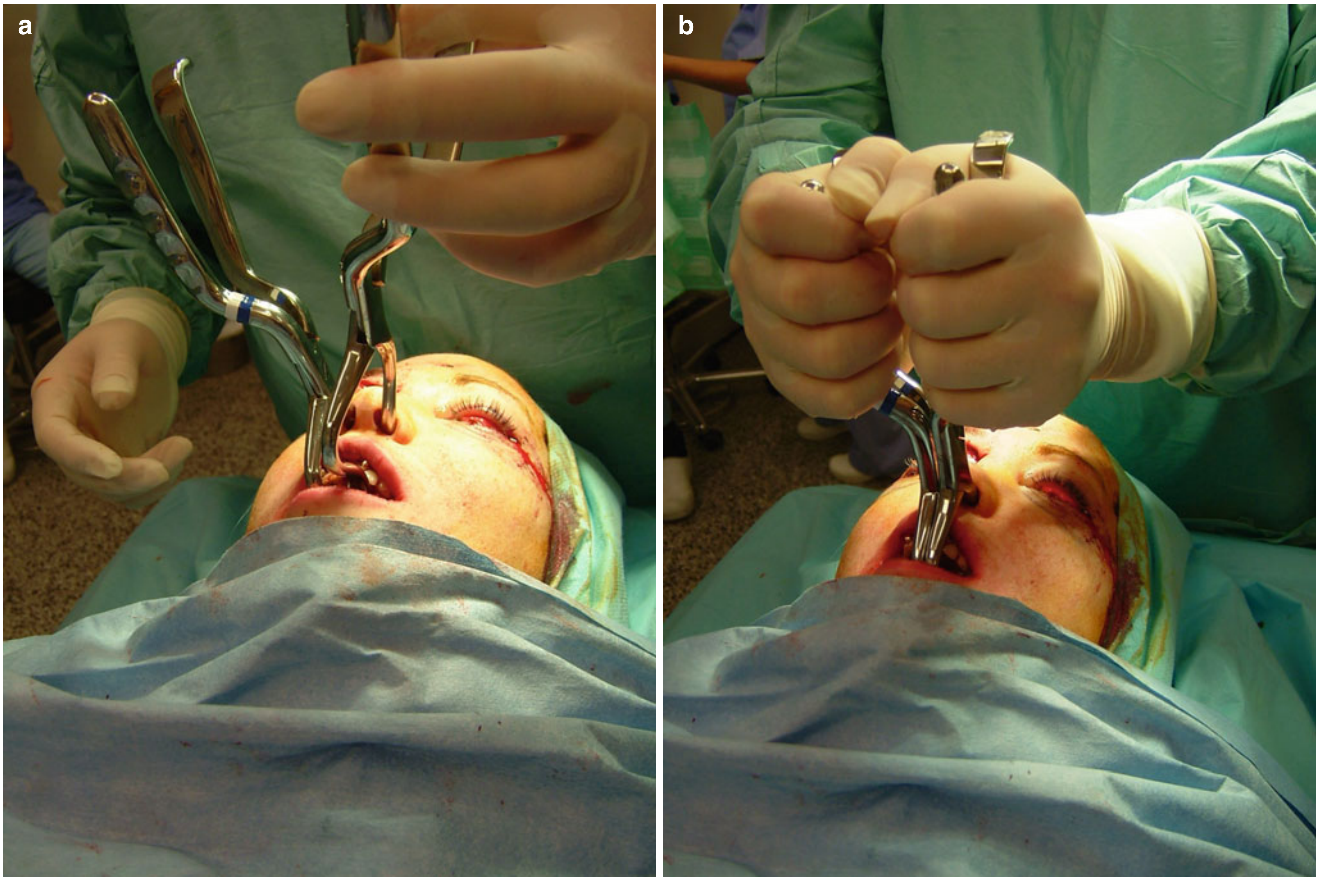

Fig. 7.18 Insertion of left instrument (**a**). When gripped as shown, both instruments can be used as one device (**b**)

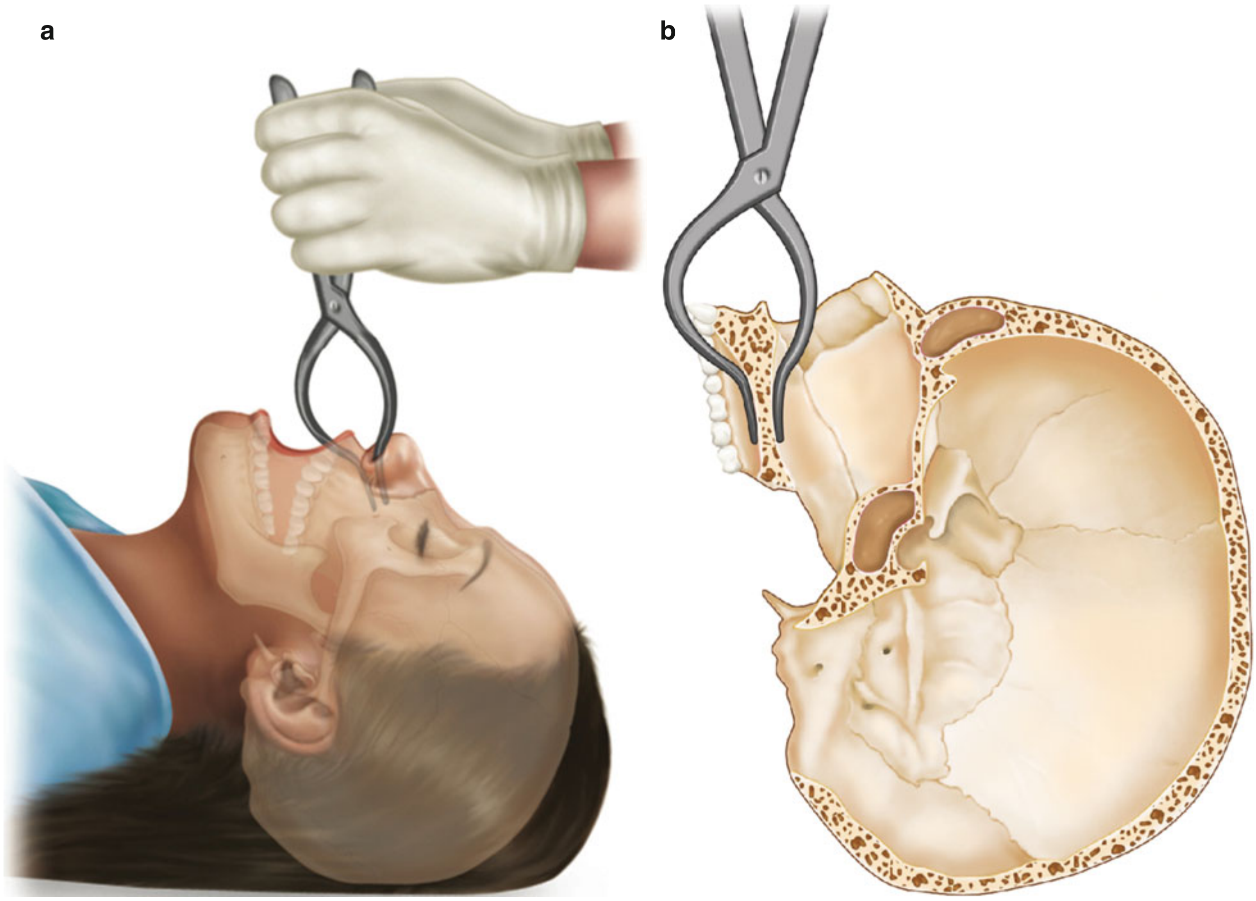

Fig. 7.19 Final position of fully seated instruments (**a**, **b**)

Case 2

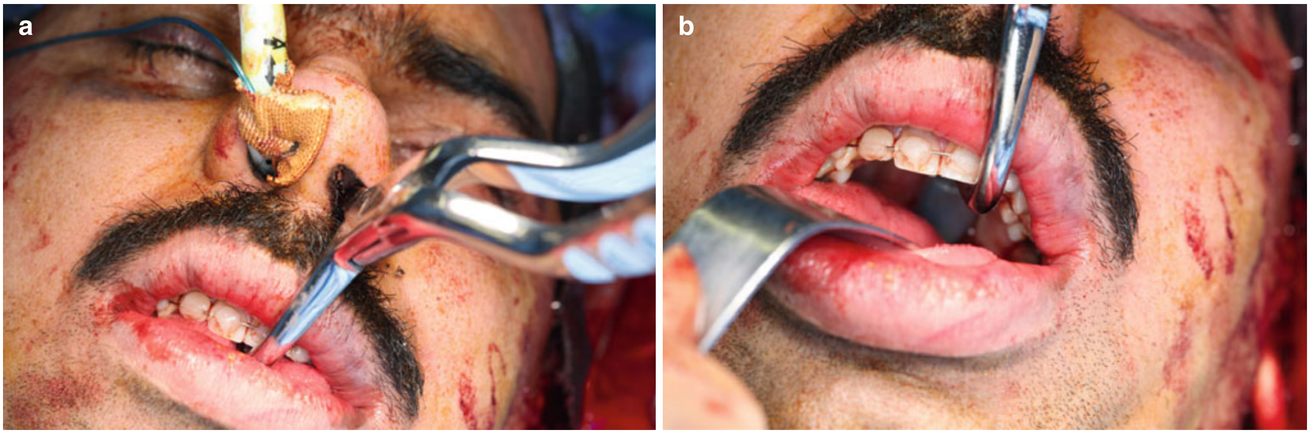

Fig. 7.20 Maxillary disimpaction of a mixed pattern Le Fort injury using a single instrument (**a**, **b**)

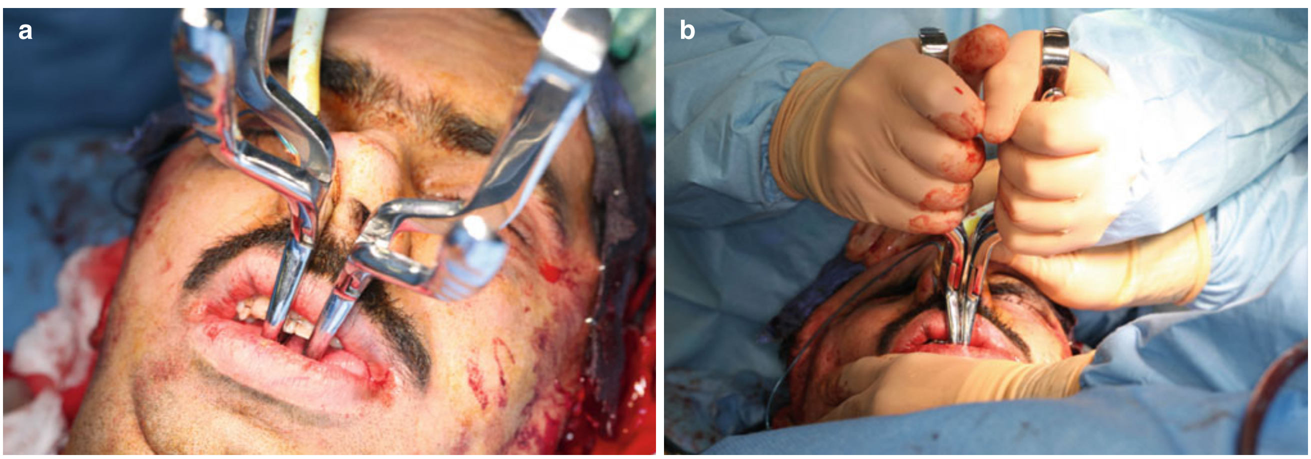

Fig. 7.21 Maxillary disimpaction using paired instruments (**a**, **b**)

If passage of the instruments through the nose is not possible, an alternative approach to disimpaction must be considered. Pterygoid disimpactors (used in orthognathic surgery) are instruments designed to engage the pterygomaxillary fissure, through which a force can be applied to bring the maxilla forward. This involves making a small mucosal incision. Alternatively, any number of other suitable flat instruments may work just as well.

7.5.3 Internal Fixation of the Midface

Internal fixation of the buttresses is usually carried out through an intraoral approach. IMF may be temporarily placed during this procedure to help realign the boney fragments. (Some surgeons prefer to maintain IMF after surgery). Fixation uses semirigid miniplates and monocortical screws. Under direct vision, the fractures are reduced and plated. For complete fixation of Le Fort II and III fractures, access may be required via periorbital incisions or a coronal flap. In the edentulous patient, Gunning splints may be useful.

7.5.3.1 Le Fort I Access (Access to Lower Midface)

Access to the lower midface can be achieved intraorally. This is through an incision that is variably termed (upper vestibular, upper sulcus, Le Fort I; see Fig. 7.22). It is the same incision used in orthognathic surgery, when undertaking a Le Fort I osteotomy. Through this incision, the entire midface can be exposed, extending upwards to the infraorbital margins and laterally over the prominences of the cheeks. Further exposure is limited by the infraorbital nerve and soft tissue over the nose, but is possible by converting this into a "midface degloving incision."

The incision is placed in the upper vestibular sulcus at least 5 mm above the upper margin of the attached gingival. This facilitates closure and avoids gingival retraction postoperatively. Although this incision can be accomplished as one full-thickness mucosal incision, straight down to bone, bleeding can sometimes be profuse and a layered approach enables better haemostasis. The incision passes from premolar region to pre-molor region. Further extension into the molar region is generally unnecessary and reduces the size of the buccal vascular pedicle. Extension may also expose and rupture the buccal fat pad. This may then require constant retraction, as herniation of its contents can repeatedly (and irritatingly) get in the way.

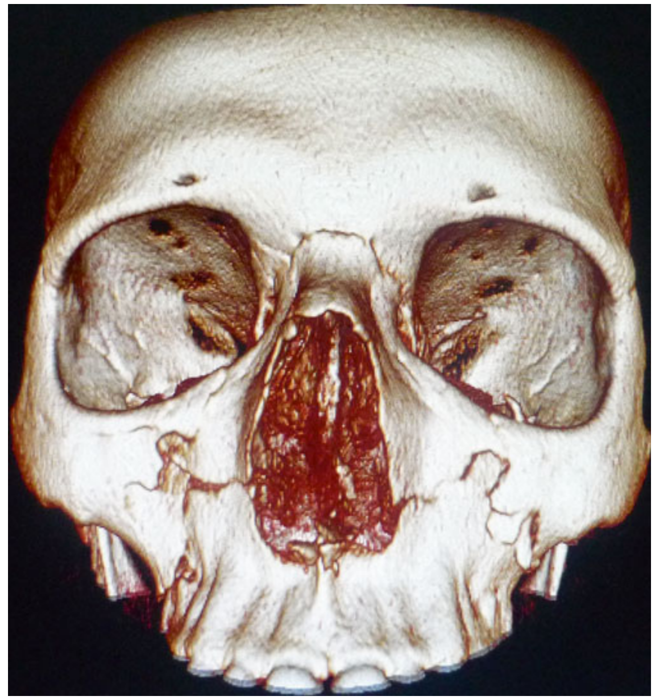

Fig. 7.22 Le Fort I fracture

In the case shown, the first incision is mucosa only. Cutting diathermy is excellent for this. It is quick, easy, and minimises blood loss. The second deeper incision is then made through the underlying muscle also with cutting diathermy. It is important to use the diathermy quickly. It can generate a lot of heat and prolonged use can result in burns beyond the incision. The final periosteal incision is made using a scalpel. The periosteum is then elevated using a sharp periosteal elevator (see Figs. 7.23, 7.24, 7.25, 7.26 and 7.27).

Case 1

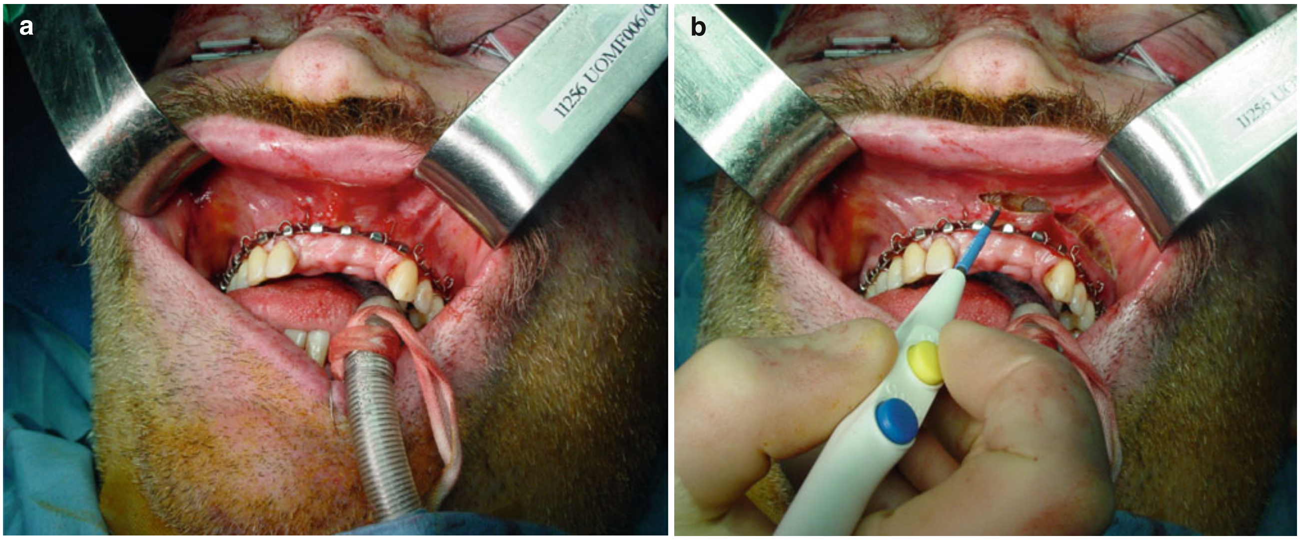

Fig. 7.23 In this case the initial diathermy incision is through mucosa only, although some surgeons prefer to cut straight down to bone in one go (**a**, **b**)

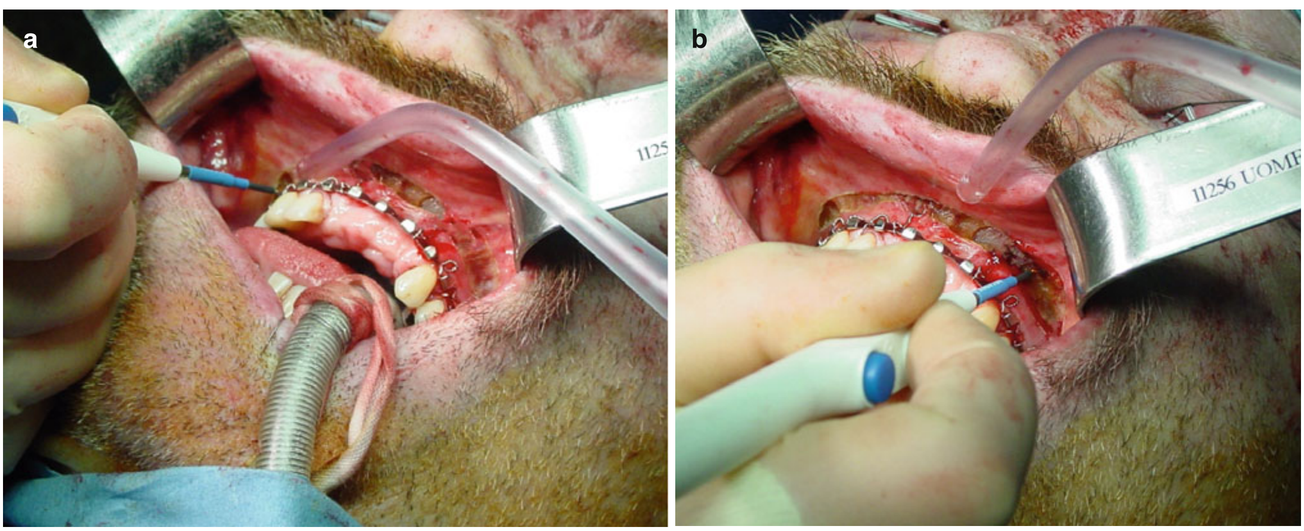

Fig. 7.24 Completion of mucosal incision (**a**), followed by muscle-cutting incision (**b**)

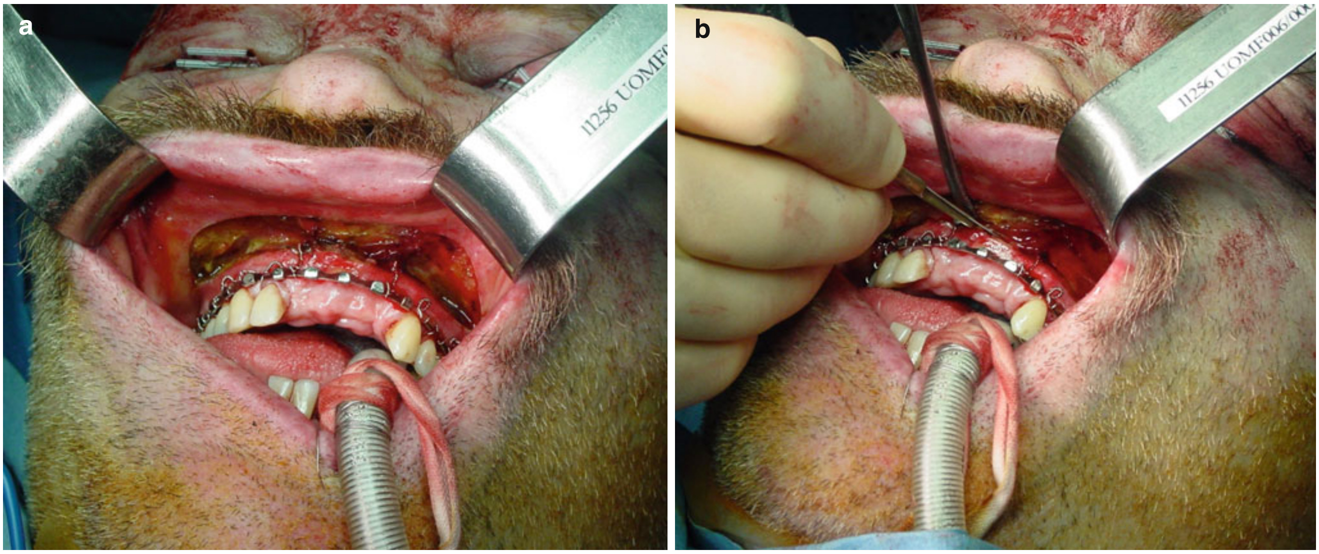

Fig. 7.25 Second incision is completed (**a**). The periosteum is then incised with a scalpel (or diathermy) (**b**)

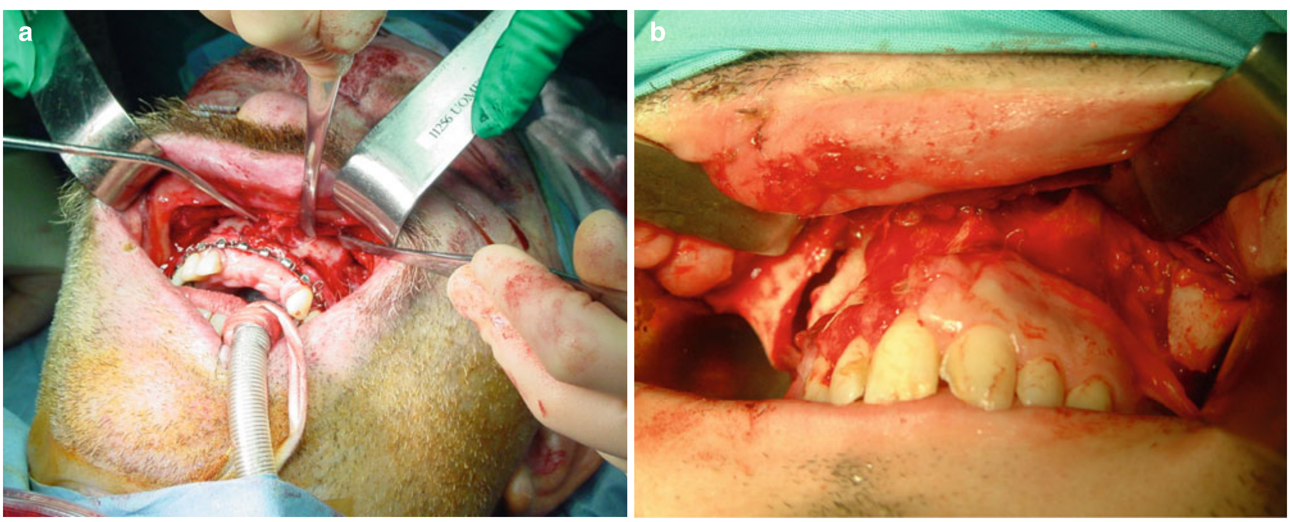

Fig. 7.26 (**a**) Periosteal elevation. (**b**) Exposure of a Le Fort I fracture in another case

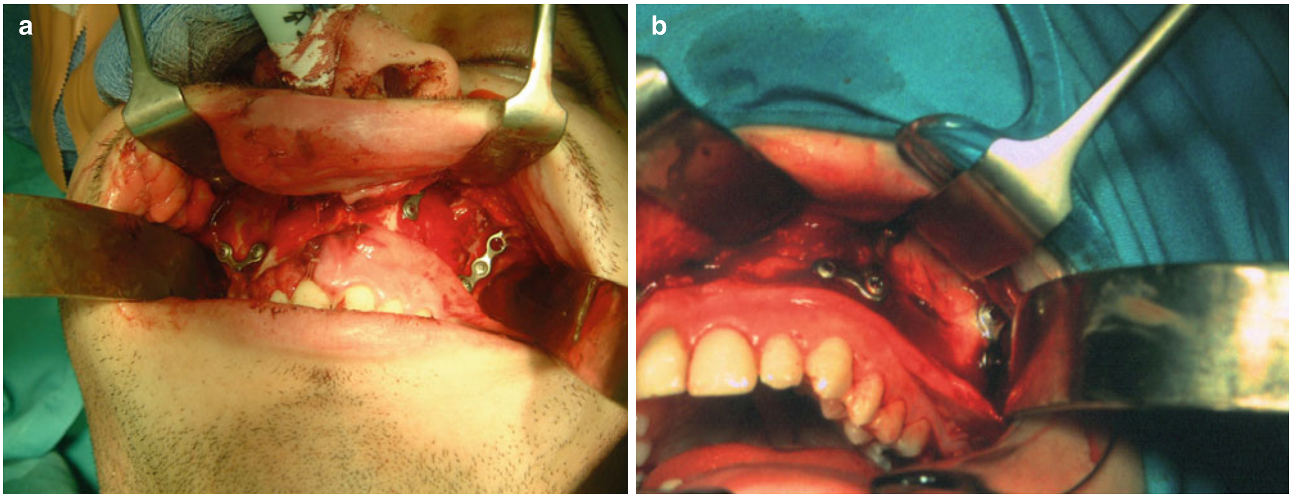

Fig. 7.27 Careful assessment of the bones is required. Only the buttresses are thick enough to support fixation hardware (**a**, **b**)

Le Fort I access is a relatively quick procedure and provides excellent exposure of the lower midface. With Le Fort II fractures, access to the infraorbital margins is also possible through this incision (although the infraorbital nerve may limit this). This is a matter of personal preference (see Fig. 7.28).

Case 2

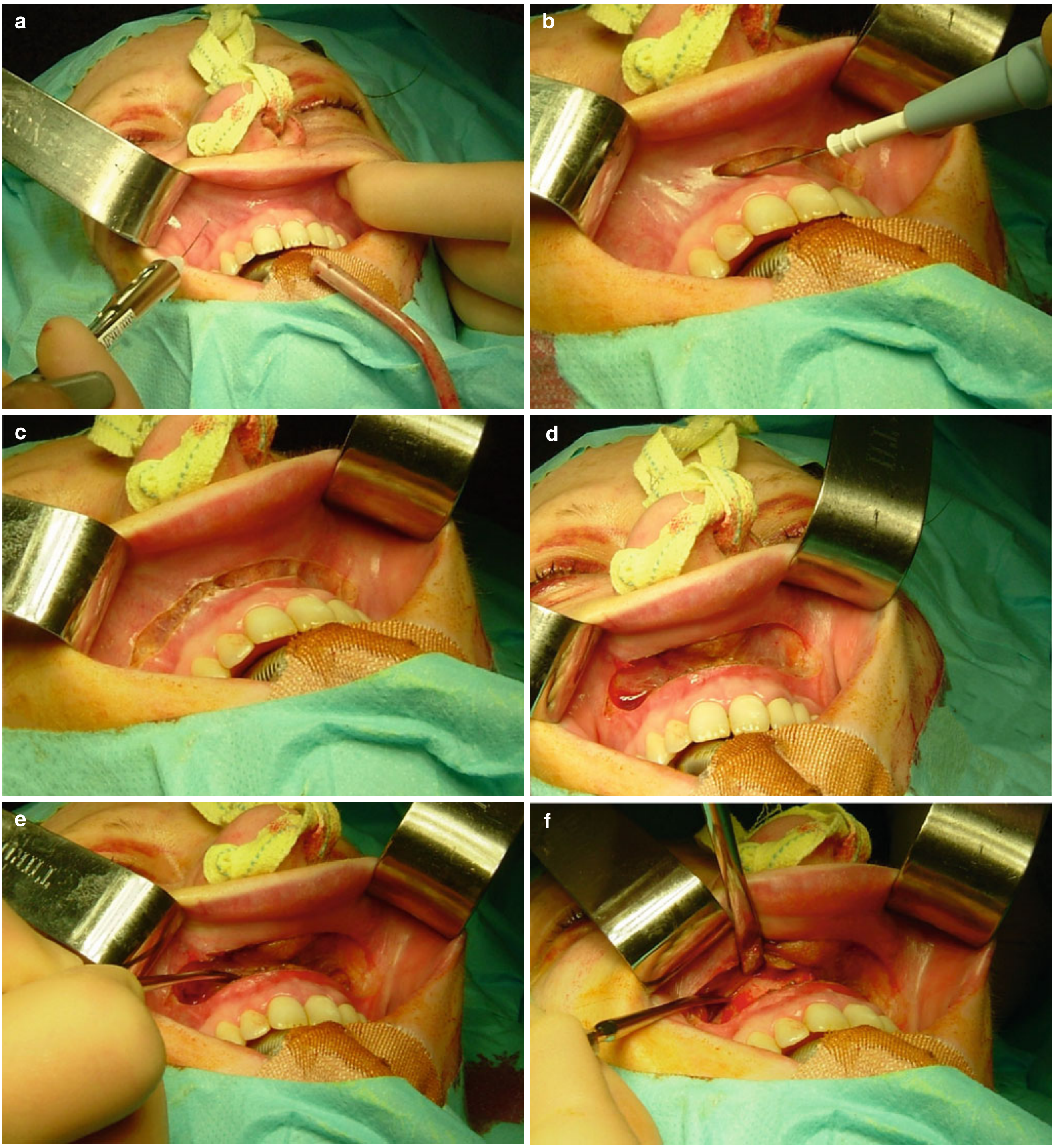

Fig. 7.28 Exposure follows the same sequence as in Case 1: three incisions prior to periosteal elevation. It can be done with one incision, but may bleed a bit more (**a**–**h**)

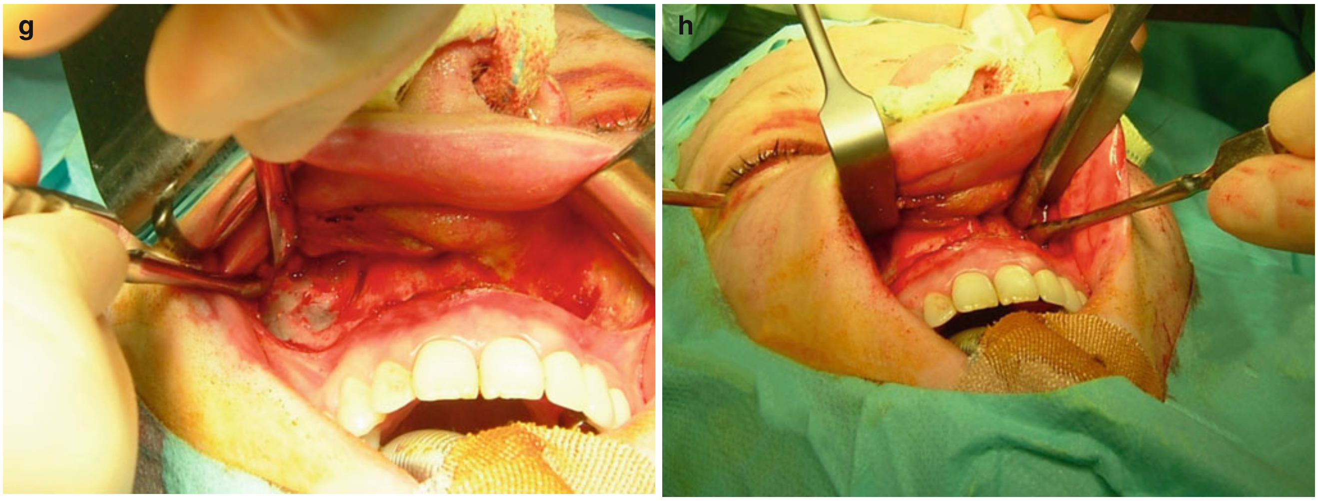

Fig. 7.28 (continued)

7.5.3.2 Comminuted Buttresses

Comminution of one or more buttresses is commonly seen after high-energy impacts. If the fragments can be reliably repaired anatomically, this is usually not a problem and the bones should heal uneventfully. However, problems may occur if the buttresses are comminuted to such an extent that anatomical repair is not possible. This can make accurate reestablishment of the occlusion or facial dimensions difficult. Fortunately, in most cases only one or two buttresses are extensively comminuted and vertical facial height can still be established. When two or more buttresses are comminuted, bone grafting may be required.

> Because of the associated soft tissue injuries, extensively comminuted fractures are at a greater risk of infection or avascular necrosis. "Rigid" fixation of the fragments and any bone grafts is therefore important. Alternatively, the fractures could be left covered and external fixation with IMF used (see Fig. 7.29).

7.5.3.3 Split Palates

In some cases, splits in the palate need reduction and fixation. The tightly bound palatal mucosa is usually torn, providing access. Plates may need to be removed at a later date, as they can become exposed, but this is an acceptable compromise if the transverse facial width is restored (see Figs. 7.30, 7.31, 7.32 and 7.33).

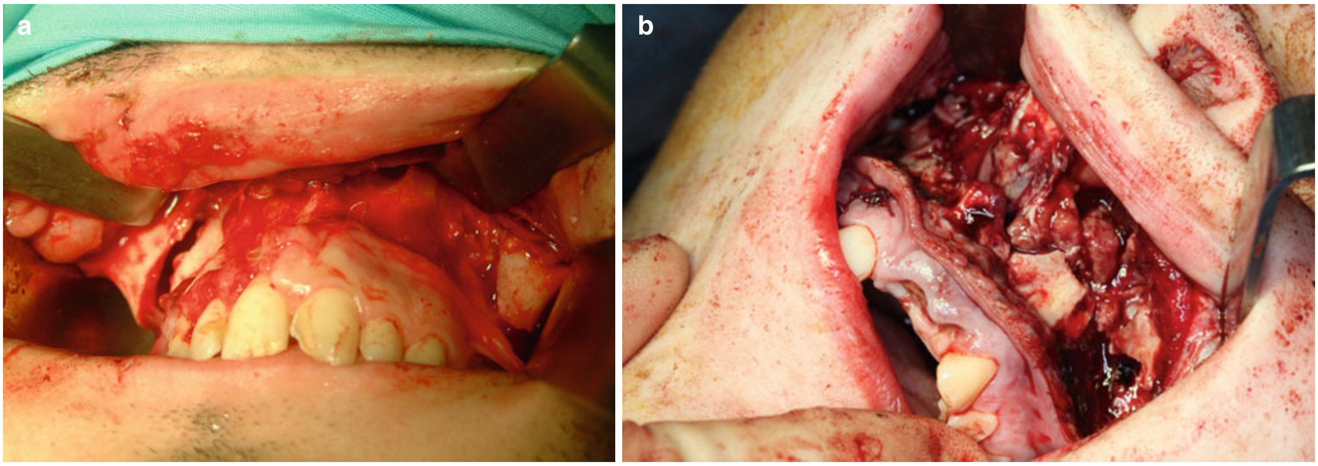

Fig. 7.29 "Simple" (**a**) versus comminuted (**b**) fractures of the buttresses. A good case for bone grafting

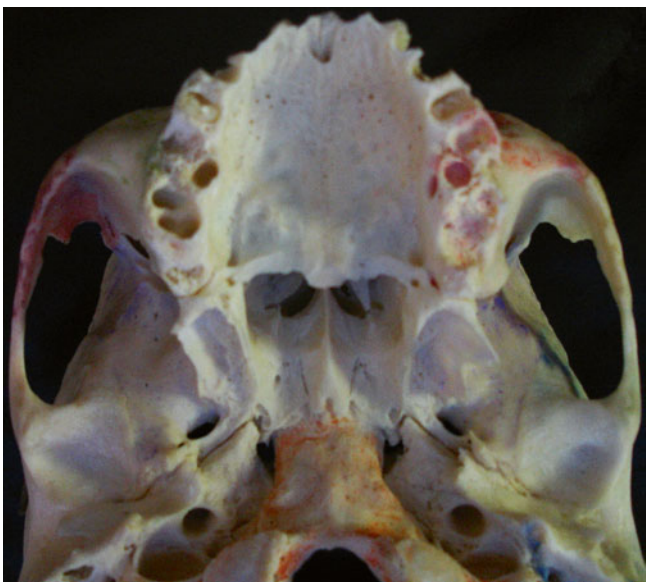

Fig. 7.30 Submental-vertex view of dried skull to show palate

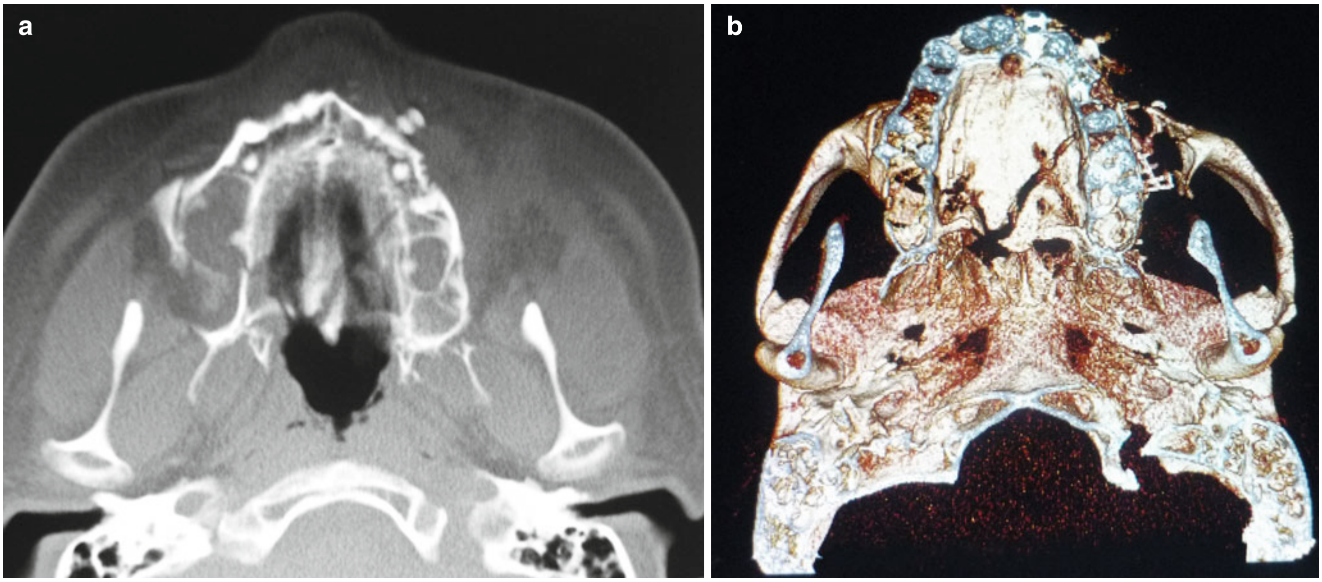

Fig. 7.31 Similar views on axial (**a**) and three-dimensional (**b**) CT, showing palatal fracture. Note bowing of the zygomatic arch

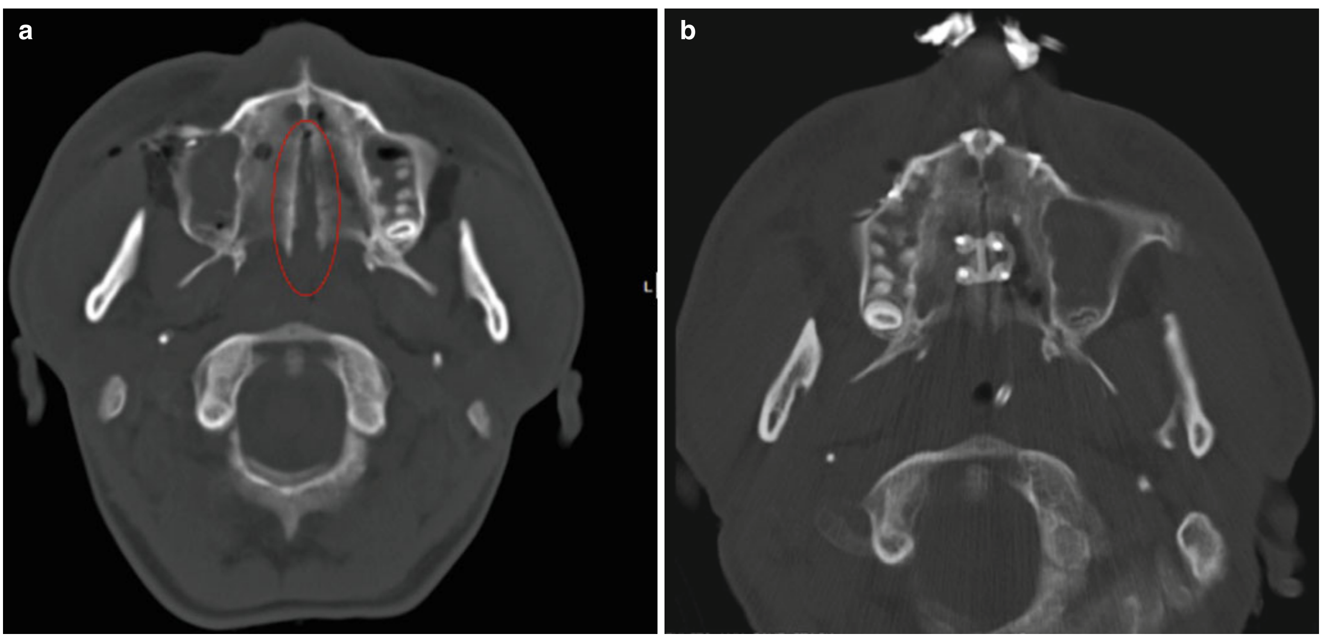

Fig. 7.32 Another example of split palate (*red oval* in **a**), requiring repair (**b**)

Fig. 7.33 Three-dimensional CT view of palatal repair

7.5.3.4 Le Fort II Access

Access to a Le Fort II fracture requires the same intraoral approach as for a Le Fort I fracture (to access the buttresses). It also requires access to the bridge of the nose and/or infraorbital rims.

In the case shown (see Figs. 7.34, 7.35 and 7.36), access to the upper part of the fracture has been gained through local incisions. Exposure of the nasal bridge was made through an overlying laceration. Access to the infraorbital rims was gained through a retroseptal transconjunctival incision (described elsewhere). The fracture was carefully mobilised and reduced, placing the patient into temporary IMF. An intraoral vestibular incision provided access to repair the buttresses, while the upper fractures were fixed, using small miniplates. Exploration of the orbital floor and walls was also undertaken through the transconjunctival incision.

Remember to pay close attention to the nasal septum. This is often fractured or deformed, resulting in loss of nasal projection. Following fixation of the Le Fort fracture, the nasal septum should be inspected and if necessary manipulated and splinted.

Because of the need for simultaneous access to the nose and IMF, submental intubation may be required. In this case the patient was partially edentulous and therefore it was not necessary (see Fig. 7.37).

7.5.3.5 Le Fort III Access

Essentially there are two ways to access the upper fractures:

1. Using local incisions (FZ approach, nasal bridge, zygomatic arch)
2. Via a coronal flap

These incisions are described elsewhere. Because Le Fort III fractures are, by definition, skull base fractures, neurosurgical complications (notably CSF rhinorrhea) are a risk. For this reason, wider access may be required (see Figs. 7.38, 7.39, and 7.40). A neurosurgical opinion should be initially sought.

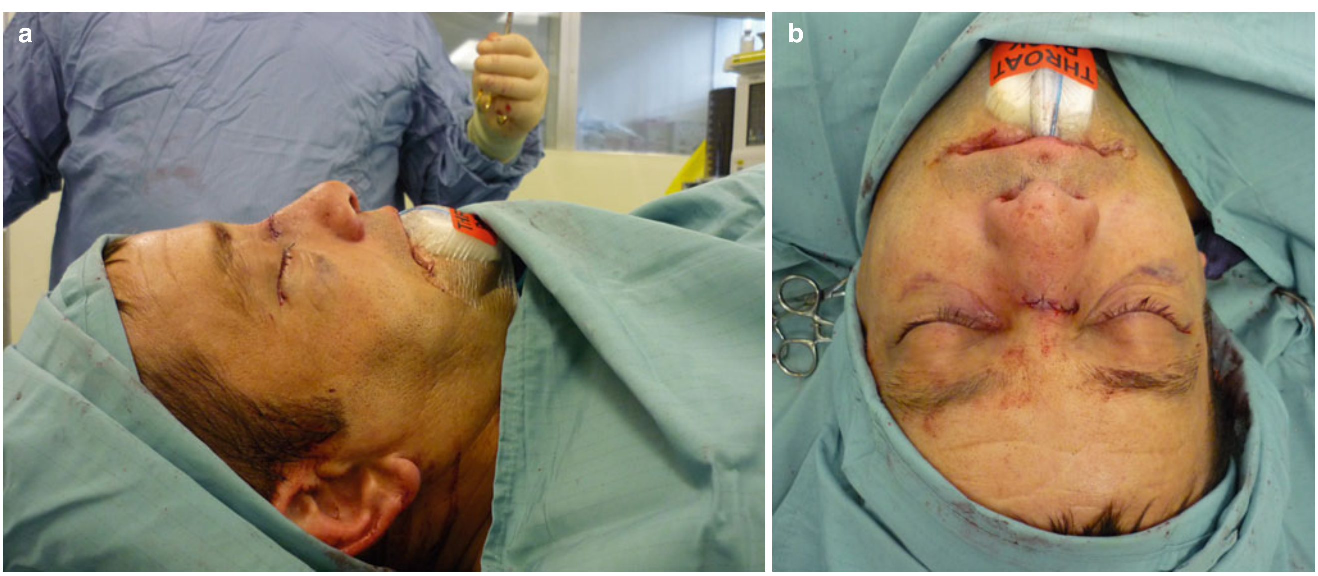

Fig. 7.34 Access to nasal bones of Le Fort II fracture through a preexisting laceration (**a**, **b**)

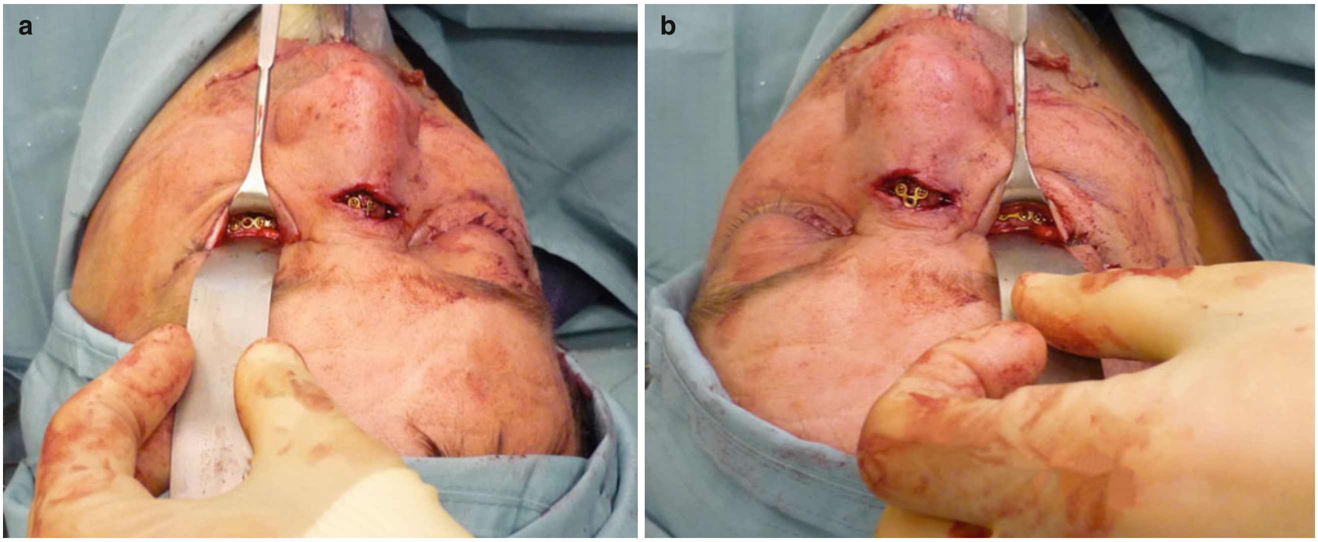

Fig. 7.35 *Left* (**a**) and *right* (**b**) infraorbital rims repair through a transconjunctival incision

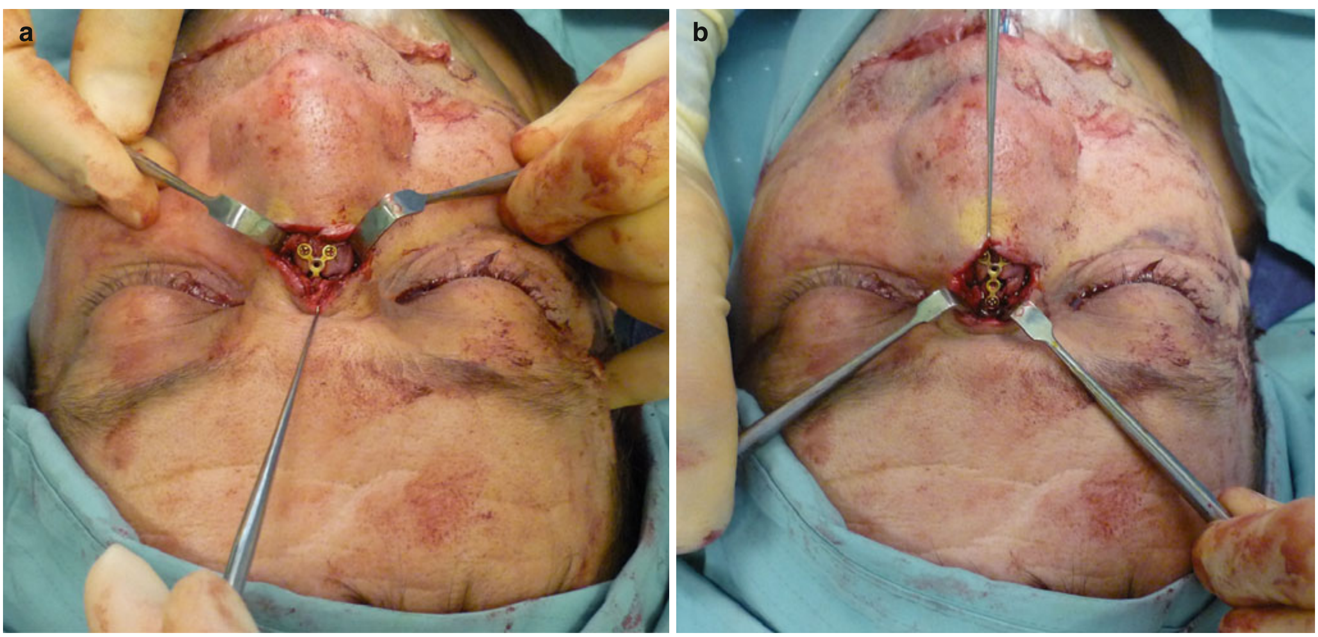

Fig. 7.36 Repair of nasal fractures through overlaying laceration (**a**, **b**)

Fig. 7.37 Another example of open reduction and internal fixation of Le Fort II fractures

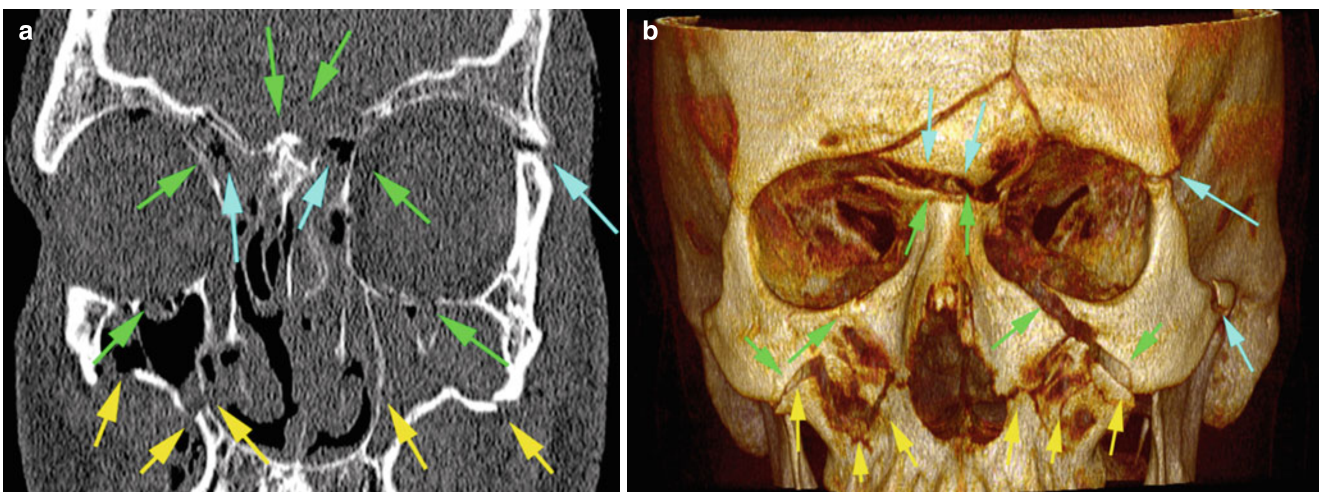

Fig. 7.38 Planning access can be difficult in some cases. Although these are extensive fractures, there appears to be no significant skull base fractures or dural tears. Clinically there was no CSF leakage. The fragments were also large, facilitating access through local incisions (**a**, **b**). Le Fort III (I); Le Fort II (*green*); Le Fort I (*yellow*); Le Fort III (*light blue*)

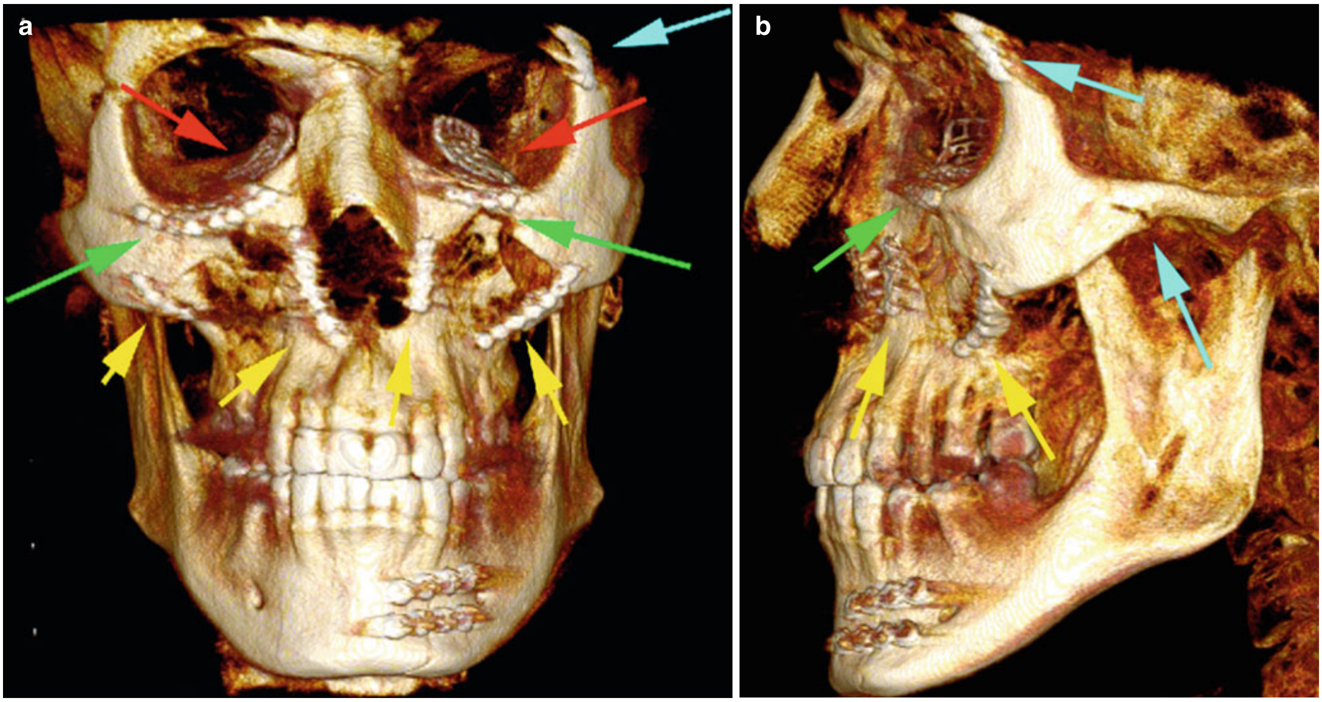

Fig. 7.39 Postoperative imaging. Not all fractures required internal fixation. A limited approach reduces surgical time and complications, but should not be used as a "short-cut" at every opportunity. In this case it was agreed following discussion with the patient (**a**, **b**) Le Fort III (*light blue*). Le Fort III (I); Le Fort II (*green*); Le Fort I (*yellow*). but in addition orbital reconstruction (*Red*)

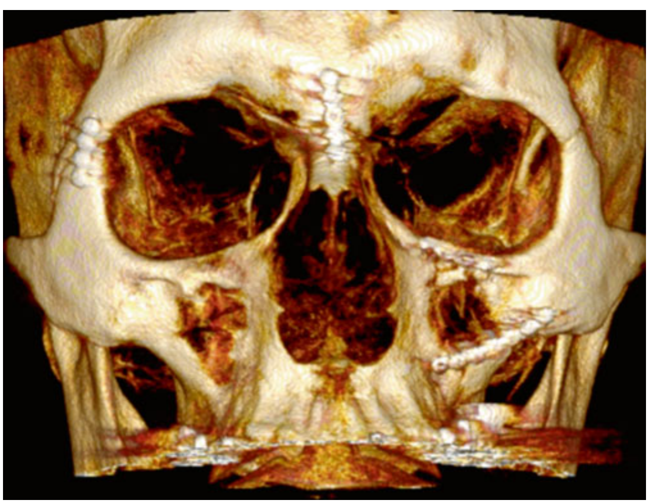

Fig. 7.40 A further example of satisfactory reduction though local incisions

7.6 External Fixation and Miscellaneous Techniques

External fixation may be indicated for blast injuries, rapid immobilisation, or in severe comminution. In such cases, the patient's occlusion is used to align the fractures, which are then immobilised by fixing them to the cranium or frontal bone. External fixation is generally carried out using supraorbital pins or a halo frame connected to the maxilla with a bar. However, this method has largely been superseded by internal fixation using plates. Nevertheless, it may still be useful when rapid fixation is required, there are infected wounds (rare), the fractures are extensively comminuted or in children. The presence of associated skull or frontal bone fractures is a relative contraindication to external fixation (see Figs. 7.41, 7.42, 7.43 and 7.44).

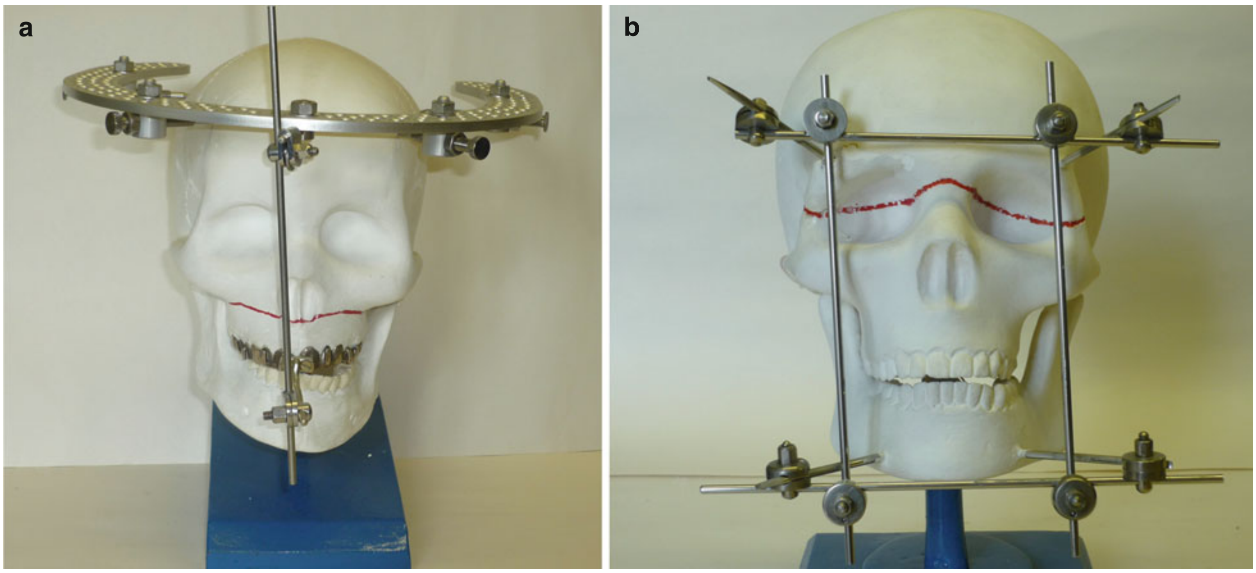

Fig. 7.41 Halo (**a**) and box frame (**b**) external fixators

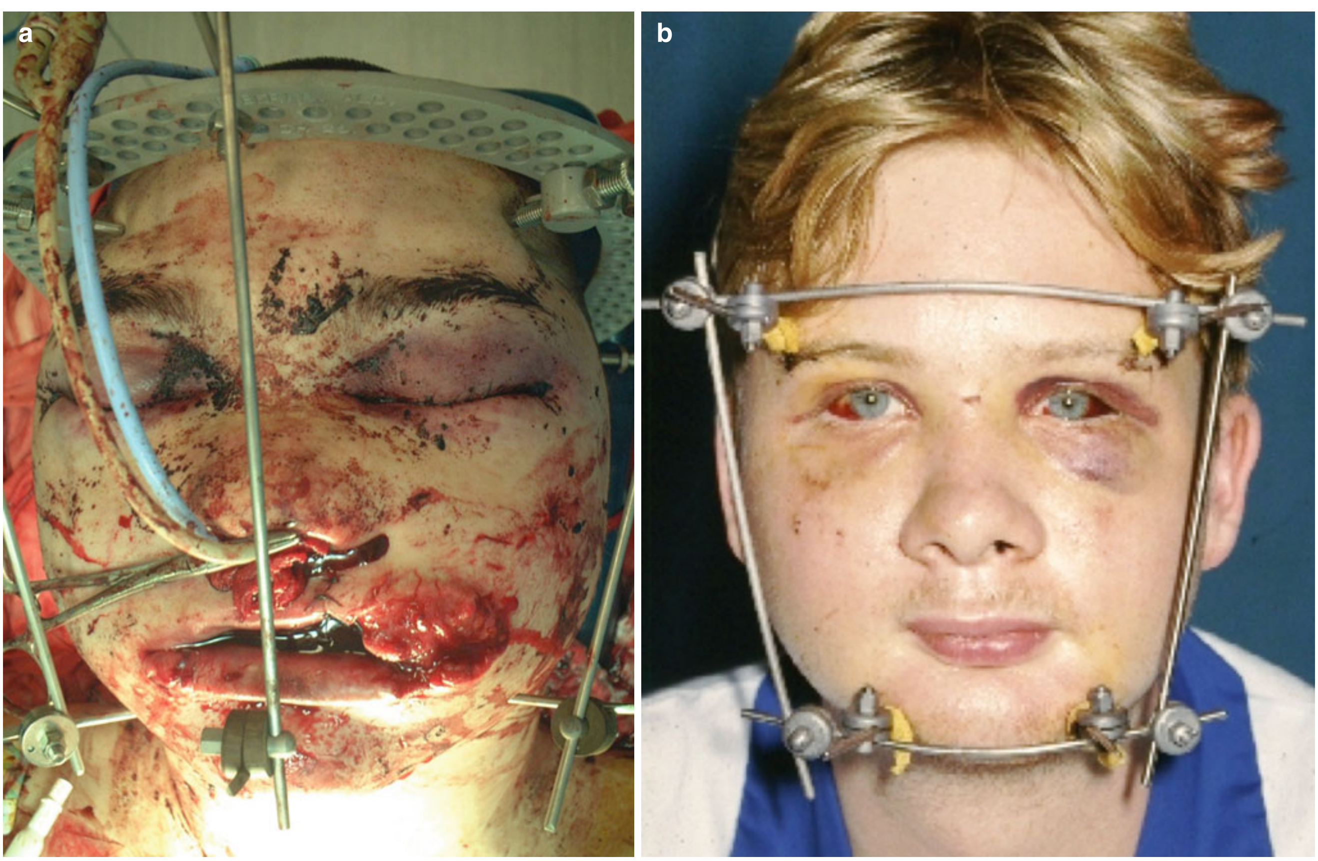

Fig. 7.42 Clinical application of halo (**a**) and box frame (**b**) external fixators

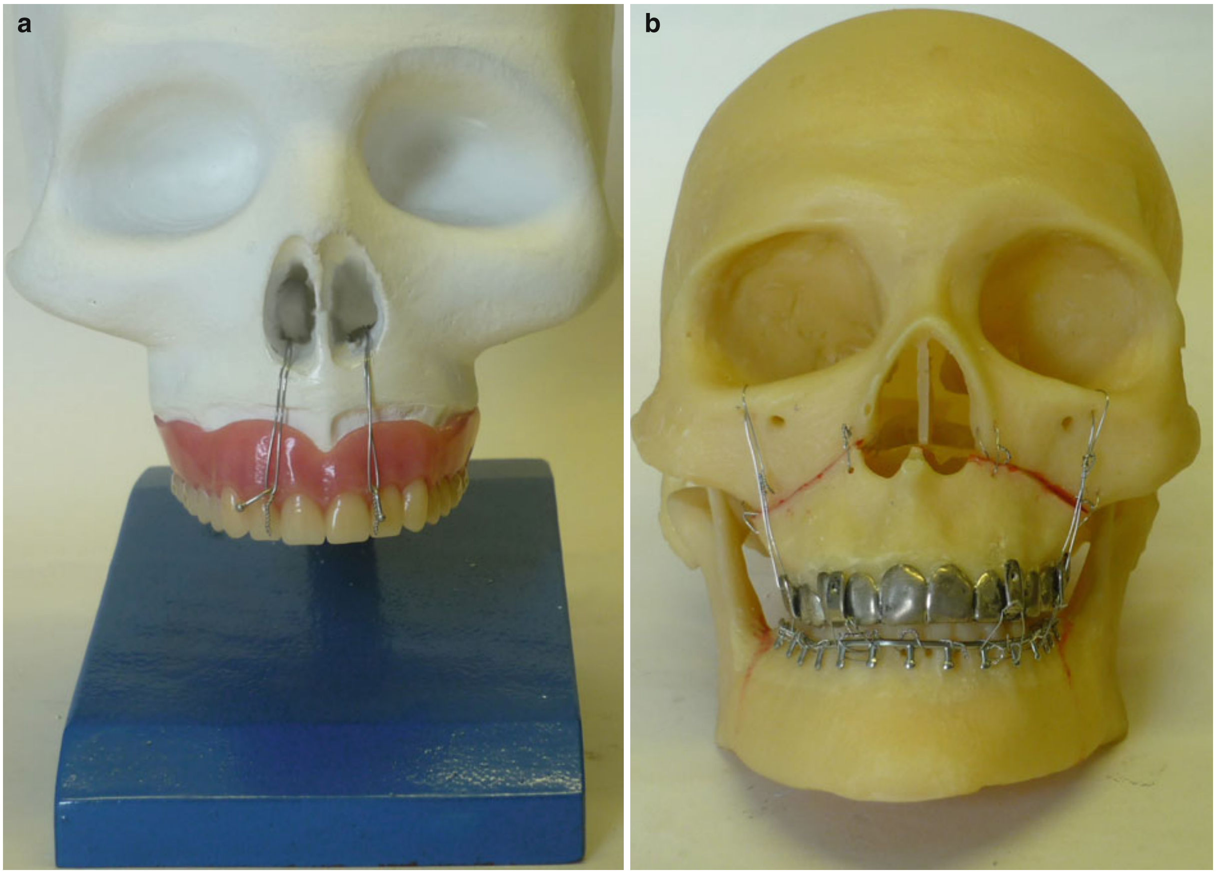

Fig. 7.43 Internal suspension wires (**a**, **b**)

Fig. 7.44 Custom-made cap splints for external fixation

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Fractures of the Cheek: Zygomaticomaxillary Complex

8

Michael Perry and Simon Holmes

8.1 Overview

Cheek fractures are extremely common injuries and comprise a spectrum from relatively simple fractures resulting in minimal aesthetic impairment, to complex patterns causing gross disfigurement and considerable functional disability. The terminology can also be a little confusing (see Table 8.1).

Table 8.1 Terminology of cheek fractures

The following terms are used to describe essentially the same injury—a fracture of the cheek prominence and adjacent bones, including the orbit:
Zygoma
Malar
Cheek
Zygomaticomaxillary
Zygomaticomaxillaryorbital
Tripod
Tetrapod

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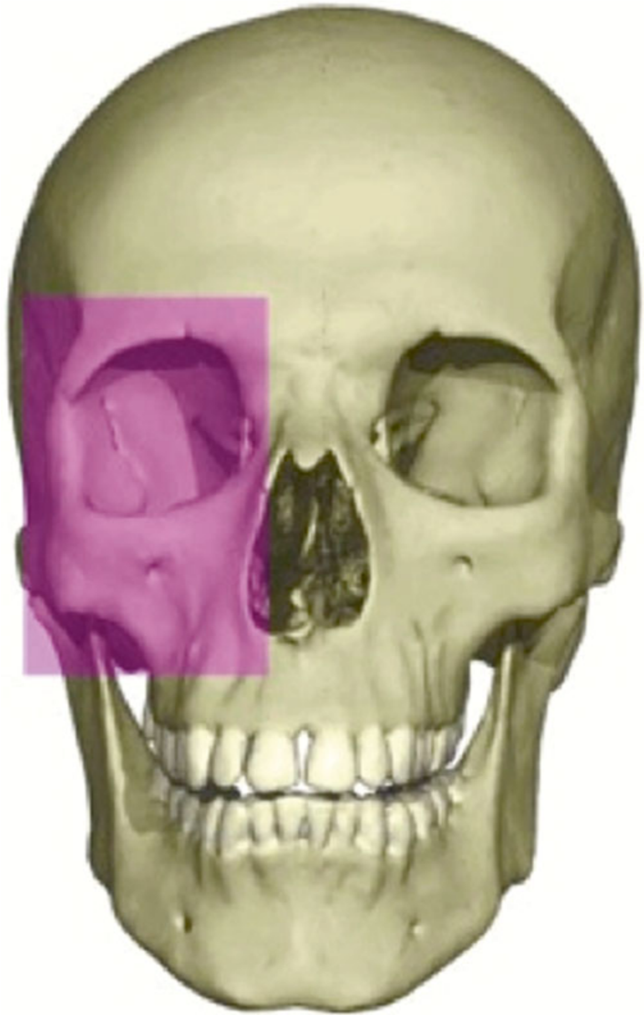

Fig. 8.1 The Zygomaticomaxillary complex

The classic description of the fracture pattern is that of a tetrapod (although they are sometimes confusingly referred to as "tripod") fractures. The "feet" or "pods" in this description refer to the main sites of fracture displacement, which can be identified either clinically or radiographically. The arch fractures separately from the remaining sites, which are bridged by a continuous ring of interlinking fractures. Conceptually these latter fractures effectively form an obliquely positioned, irregular-shaped ring of fracture. Together with the arch fracture this allows separation of the entire zygomaticomaxillary complex (ZMC) from the rest of the facial skeleton (see Figs. 8.1, 8.2, 8.3 and 8.4).

Although commonly seen "en bloc, fractures of the zygoma are a good illustration of how varied these injuries can be as the energy of impact increases. As the energy transfer increases from mild to moderate to severe, fracture complexity increases correspondingly, with progression to comminution and extension beyond the confines of the ZMC. Management can therefore vary widely.

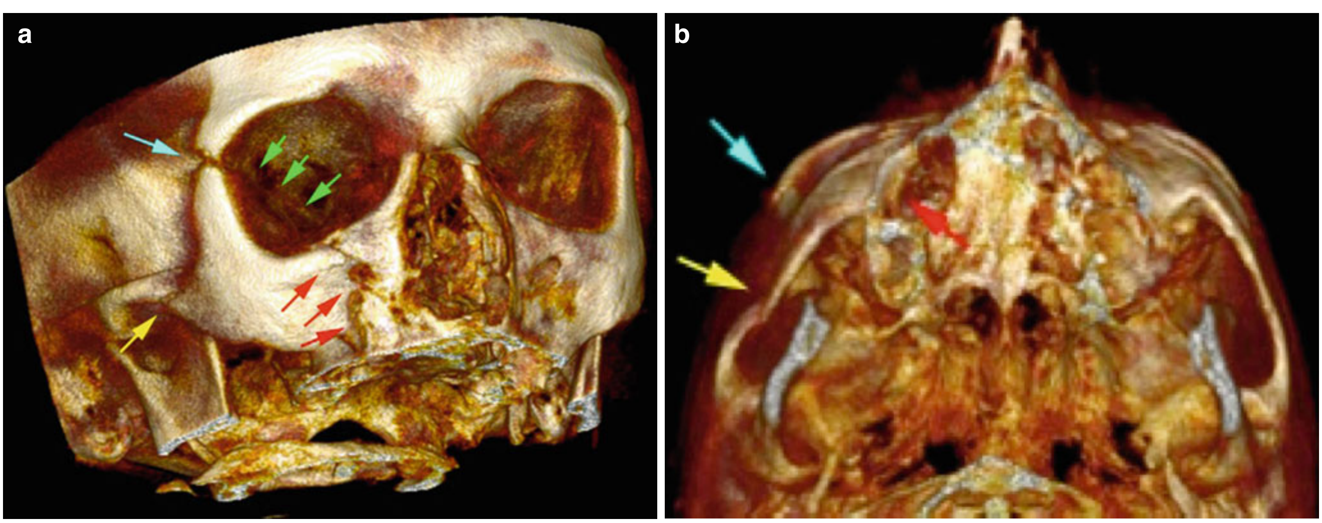

Fig. 8.2 CT of a fracture of the ZMC. The fractures and separation are colour-coded: *red* indicates separation through the zygomaticomaxillary region, *green* indicates sphenozygomatic junction, *yellow* indicates zygomaticotemporal region (arch), and *blue* denotes disruption of the fronto-zygomatic region). Such injuries are indicative of low to moderate energy transfer

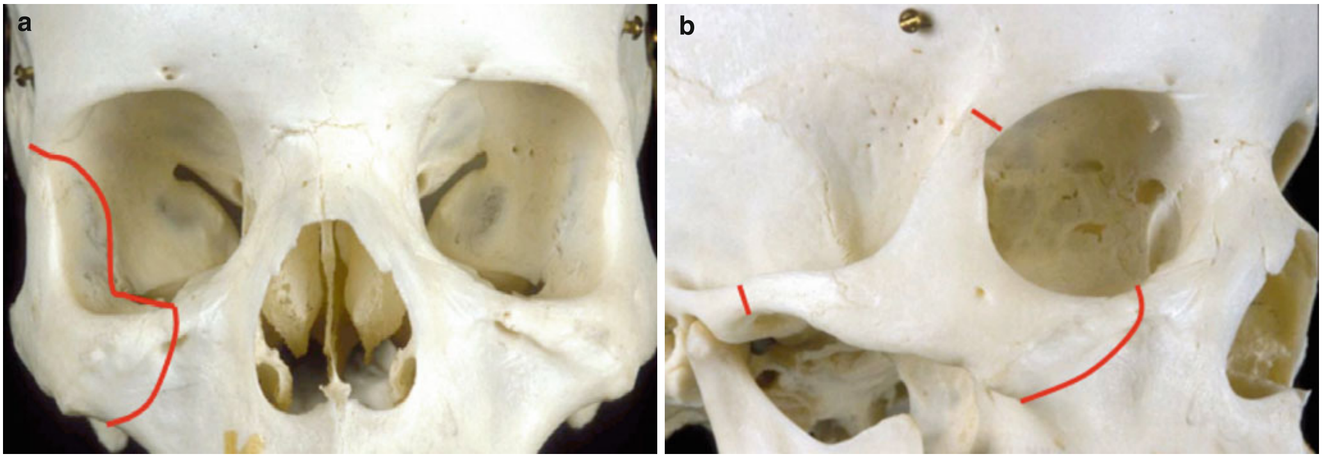

Fig. 8.3 More simplistically, the "classical" ZMC fracture can be regarded as a fractured block of bone involving the prominence of the cheek, arch, orbital floor, and lateral orbital wall

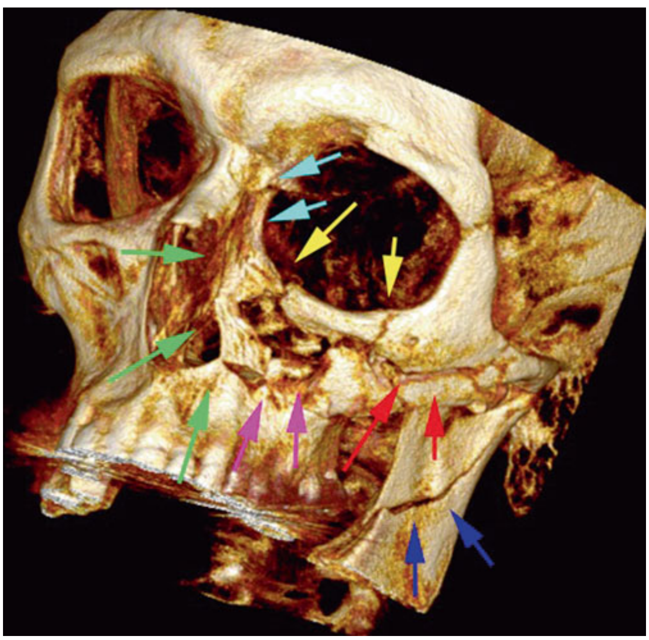

Fig. 8.4 This case demonstrates another fractured zygoma *red arrows*, which is much more severe. The *yellow arrows* demonstrate the three-part fractured inferior orbital margin, the *purple arrows* indicate the comminuted anterior maxillary wall. The *green arrows* show the progression of the anterior maxillary wall fracture onto the piriform aperture. This can result in the medial orbital margin collapsing into the nose (*light blue arrows*). The extended fracture of the coronoid process and condyle (*dark blue arrows*) is a direct result of medialisation of the entire zygomatic bone

8.2 Applied Anatomy

Knowledge of the anatomy of the zygomatic complex, together with an understanding of the different fracture configurations, is important to help in the planning of repair.

8.2.1 Overview of the Bones

The "cheek bone" is formed predominantly by the zygomatic bone. This has a superior process, which fuses with the frontal bone at the frontozygomatic (FZ) suture alongside the eyebrow. This is a key site for osteosynthesis. Not only is it easily accessible, but the bone is also particularly robust, enabling strong plate fixation. Furthermore, fractures at this site typically occur across the suture, allowing precise reduction of the bone. Even in severe injuries the fragments can usually be pieced together reliably, reconstituting this landmark.

Medially, the zygoma joins with the infraorbital rim of the maxilla approximately two-thirds of the way along the rim. This is a more difficult region to repair as the bone is often segmented and thinner. However, precise reconstruction here is important as it restores the transverse projection of the cheek and provides support for the lower eyelid.

Posteriorly, the zygoma fuses with the temporal bone both along the zygomatic arch and the lateral orbital wall. Correct alignment of the arch is important to reestablish the anteroposterior positioning of the malar prominence. However, accomplishing this may require a more extensive soft tissue exposure.

Anteriorly, the bone fuses with the anterior wall of the maxilla, extending medially to the piriform aperture. The lateral aspect of this bone is robust, comprising one of the maxillary "buttresses." Even when comminuted, this lateral wall can usually be pieced together, using its fragments as "free grafts." Together with the use of strong fixation plates, this avoids the need for primary bone grafting in most cases. Precise repair also helps verify the correct orientation of the cheek in three dimensions. Similarly, the piriform aperture can usually be repaired using the fragments as free grafts. However, the bone intervening between these key sites is much thinner and more difficult to repair. This is not usually critical, but it may be important in patients with thin overlaying soft tissues. In these patients, loss of anterior support can result in hollowing of the cheeks.

The body of the zygoma therefore forms the prominence of the cheek. Together with the supraorbital ridge it provides a degree of protection to the globe. The bone provides support to the soft tissues, particularly the lower eyelid and the medial and lateral canthal tendons. Disruption at these sites results in obvious asymmetry and lateral canthal descent, sometimes termed an "antimongoloid slant" (see Fig. 8.5). The bone also provides support to the overlaying soft tissues through several suspensory ligaments. These may be disrupted either by the trauma itself or following detachment by the surgeon during repair. If the soft tissues are inadequately supported following repair, this can lead to the appearances of premature ageing as they begin to sag.

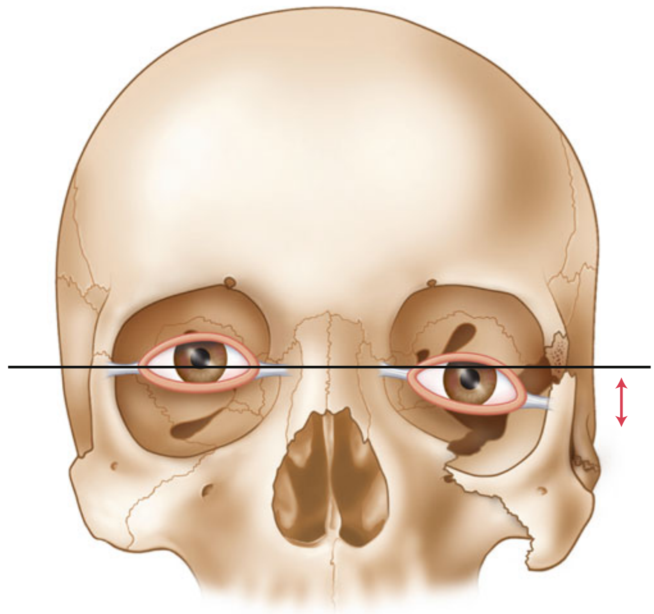

Fig. 8.5 Displacement of the zygomatic complex (ZMC) affects eyelid function and places the globe at risk of further injury. Vertical displacement lowers both the lateral canthus and the lateral attachment of Lockwood's suspensory ligament, which maintains the globe's vertical position. This results in diplopia, hypoglobus, and an "antimongoloid slant" to the eye

The zygomatic arch is a key "strut" in maintaining the forward projection of the cheek. In complex fractures, the arch can either collapse in on itself (in a "concertina" type pattern), or the fractured ends can overlap—sometimes referred to as "telescoping" (see later). In either event, this displacement needs to be carefully addressed. Fixation of the arch may or may not be required (see Fig. 8.6).

8.2.2 Soft Tissue Attachments

The temporalis muscle arises from the side of the skull. It passes downwards under the zygomatic arch and inserts into the coronoid process of the mandible. Any significant medial displacement of the arch or body of the zygoma can therefore impede mouth opening by interfering with its function (see Figs. 8.7 and 8.8).

The temporalis muscle is invested in temporal fascia, which arises from the skull and passes downward to insert

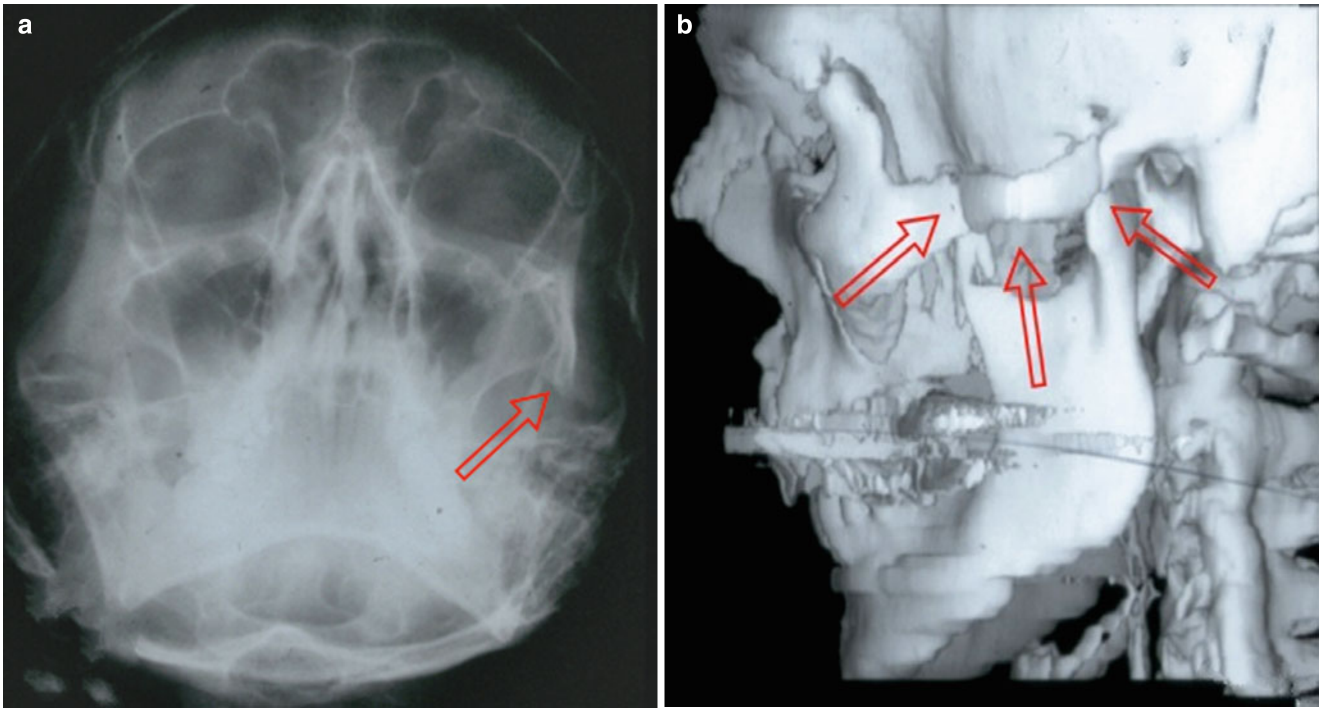

Fig. 8.6 Fractured left zygoma with medial collapse of the left zygomatic arch (*red arrows*) (**a**, **b**). Although significantly displaced, there is no overlap or separation of the arch fragments. This would imply that the periosteum is still intact and that the arch may not necessarily require internal fixation (see text for discussion)

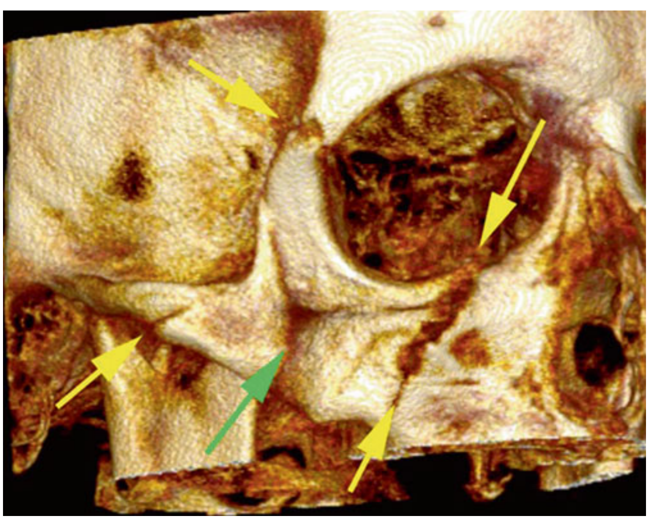

Fig. 8.7 Medial displacement of the zygoma will impinge on the function of temporalis and interfere with movement of the coronoid process. The point of impaction (*green arrow*), has resulted in fragmentation with medial displacement. *Yellow arrows* indicate the classic tripod zygomatic body fracture

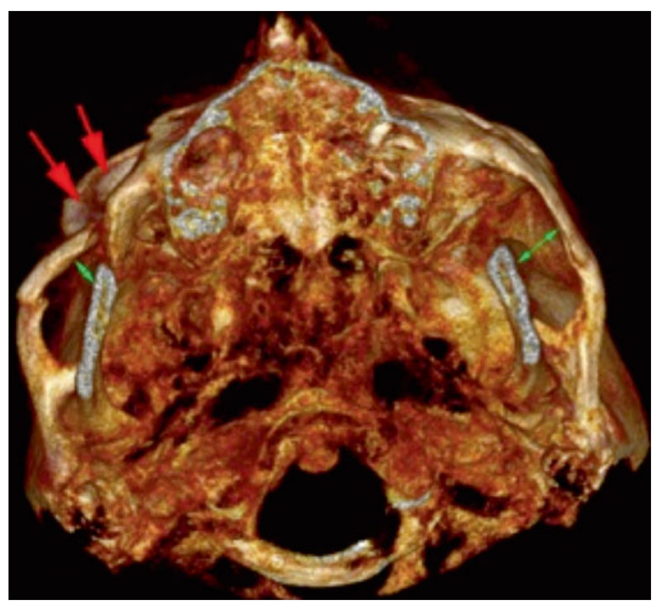

Fig. 8.8 When viewed from below, the effect of the force and fragmentation is better appreciated. The *red arrows* show the posteromedial displacement of the bone. The lack of space on the right-hand side is demonstrated by the smaller *green arrow* compared with the left side

along the zygomatic arch. This is an important surgical landmark during a “Gillies lift” (described later). The masseter muscle passes up from the ramus of the mandible and is attached to the body of the zygoma and arch. This may be an important cause of postoperative displacement in fractures that have not been fixed. It is argued that displacement can occur from intermittent pull of the masseter during function (eating) (see Fig. 8.9).

Several facial muscles are attached to the periosteum of the zygoma and maxilla. There are three sites of ligamentous attachment that may be detached as a result of injury, or following surgery to access the fragments. Of particular importance are the buccal mandibular retaining ligaments, which suspend the buccal fat pad. Attention to this is important for optimal aesthetic results. The orbital retaining ligaments may be detached during FZ exposure, and the zygomatic retaining ligaments may be detached when raising a coronal flap. In extensive injures, wide exposure of the bones may be required to allow precise repair. This involves detaching (or degloving) part or all of these ligaments. Resuspension of the soft tissues, so they may reattach, is therefore very important during wound closure. This minimises sagging of the soft tissues of the cheek postoperatively (see Fig. 8.10).

The infraorbital nerve provides sensory innervation to the majority of the cheek and the ipsilateral half of the nose and upper lip. This passes along the floor of the orbit and exits the infraorbital foramen approximately 1 cm below the infraorbital rim, midway along its length. The infraorbital canal and foramen form a plane of weakness in the bone and fractures often pass nearby. This nerve is at risk both during injury (from boney impingement) and during repair.

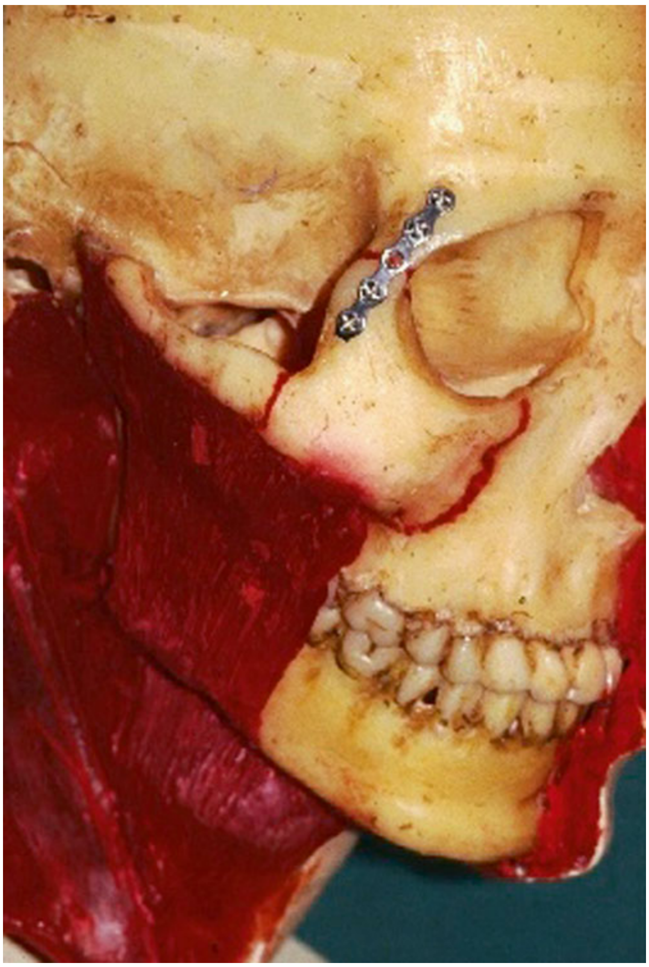

Fig. 8.9 The masseter muscle attaches to the under surface of the zygomatic body and the arch. In theory, this could produce instability following reduction without fixation. In practice this is not often significant. The arch derives its blood supply from the muscle and any detachment as a result of surgery could lead to resorption

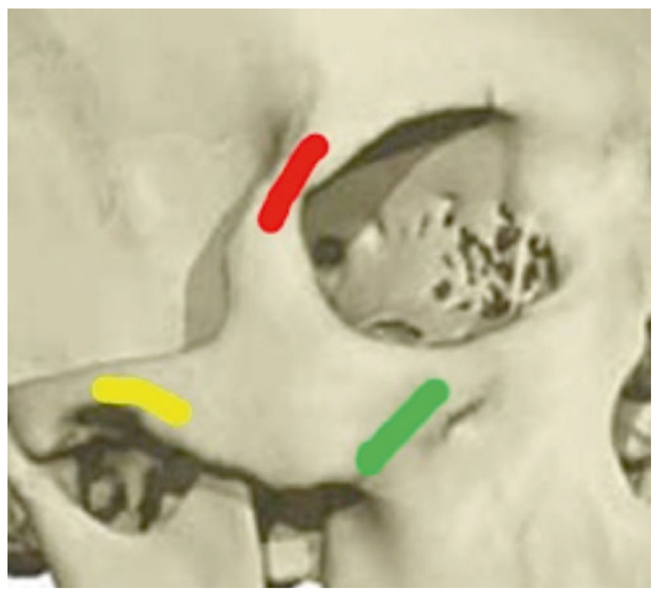

Fig. 8.10 Ligamentous attachments to the zygoma. These support the soft tissues. Of particular importance are the buccal mandibular retaining ligaments (*green*), the orbital retaining ligaments (*red*), and the zygomatic retaining ligaments (McGregor’s patch, *yellow*)

8.3 Clinical Assessment

Many authors have attempted classification of these injuries. However, these are now mostly historical, as modern surgical techniques have rendered management based on their application largely obsolete. Previous classifications attempted to draw inference from either rotation around key landmarks (Rowe and Williams), types of displacement (Knight and North) or patterns of fracture (Jackson). Others have focused on key displacements (FZ suture, Henderson). Today, with current fixation techniques, it is perhaps more useful to conceptualise these injuries with respect to the type and direction of displacement, sites of fractures, and degree of comminution, and to focus on the surgical approaches and types of fixation required. A practical classification is shown in Table 8.2.

Because all zygomaticomaxillary fractures by definition involve the orbit, patients should be assessed early for ocular injury, diplopia, and entrapment of the orbital soft tissues. The eye always takes priority.

Always consider the following:

- Globe/ocular muscle injury
- Orbital compartment syndrome/retrobulbar haemorrhage
- Superior orbital fissure syndrome
- Orbital apex syndrome

Clinical features of fracture of the zygomatic complex are shown in Table 8.3.

Table 8.2 A classification of zygomatic fractures (several exist)

Segmental fractures: zygomatic arch; infraorbital rim
Minimally displaced
Displaced fractured
Comminuted fractured
Associated with midface or complex orbital fractures
Associated with overlying lacerations/ocular injuries

Table 8.3 Clinical features of Fracture of the zygomatic complex

Pain, periorbital bruising and swelling
Flattening of malar prominence (often initially masked by swelling)
Palpable infraorbital step
Subconjunctival haemorrhage and chemosis
Antimongoloid slant
Enophthalmos, exophthalmos, or hypoglobus (vertical ocular dystopia)
Limitation of eye movements with diplopia
Altered sensation of cheek/upper lip
Restricted jaw movements
Surgical emphysema
Unilateral epistaxis (due to bleeding into maxillary sinus)
Dysocclusion (premature molar contact due to flexing of the ipsilateral half of the upper dental arch)

> Apart from isolated fractures of the zygomatic arch, nearly all other fractures of the zygomaticomaxillary complex involve part of the orbital floor and lateral orbital wall. Therefore assessments of the orbit (and eye) are an important part of management. The eye always takes priority.

8.3.1 Investigations

These are listed in Table 8.4. For most suspected fractures, occipitomental views are usually sufficient to determine (or exclude) their presence. In conjunction with a thorough clinical examination, treatment can usually be planned in the majority of cases. Although the eye takes priority, routine referral of *all* fractures for an ophthalmic or orthoptic assessment is open to debate. While some authorities feel all cases should be screened, others do not and only refer according to specific criteria. The best advise is to know your local ophthalmic colleagues and follow local protocols. If any concerns exist, however, it is always best to err on the side of caution, particularly if orbital exploration is being considered as part of the treatment. Visual disturbances and diplopia are common indications for referral. With higher energy impacts, the likelihood of "deeper" or more complex injuries is greater and CT scanning should be considered.

Table 8.4 Investigations

Visual Acuity
Plain radiographs Occipitomental (OM) Lateral face Submental–vertex (SMV) (Assess these views carefully—sometimes the only clue is a fluid level in the antrum)
CT scan: axial and coronal. These are increasingly used in patient evaluation. Indications include high-energy injuries (is the orbital apex involved?), suspected orbital floor involvement, comminuted or severely displaced fractures, other midface fractures suspected, assessment of the arch.
Ultrasound has been reported as useful for detecting fractures, but is not commonly used.
Maxillary sinus endoscopy for orbital floor fractures (not commonly used).
Comprehensive orthoptic assessment (not just a Hess chart)
Force duction test under local anesthesia (should detect entrapment of orbital soft tissues)

8.3.1.1 Interpreting Occipitomental Views

To the inexperienced, interpreting occipitomental (OM) images can be tricky. This is probably due to a combination of complex anatomy, superimposition of the skull (notably vascular markings and sutures), and the relatively oddly angled views compared with images taken elsewhere in the body. The best way to learn is to see plenty of examples. Many can now be found on the Internet. A number of useful approaches have been described to help in interpretation (see Figs. 8.11–8.13).

8.3.1.2 Interpreting Computed Tomography Scans

Although interpretation of plain films is common practice in most accident and emergency departments, their value in the precise determination of fractures remains limited. Modern surgical techniques now demand advanced imaging, which usually means CT scanning. CT data can now be enhanced using Digital Imaging and Communications in Medicine (DICOM) viewers on most personal computers. This is rapidly becoming a standard of care and will in time render plain films obsolete for all but the simplest of fractures. Conventional "head scans" produce slices typically between 3 and 5 mm thick and their diagnostic potential in midface trauma is minimal. Dedicated facial scans are needed. These are usually around 1 mm in thickness and must be assessed in all three planes of view. Axial views are especially important to assess the zygomatic arch, orbital apex, medial orbital wall, and lateral orbital wall. Coronal views assess the medial wall, orbital floor, and skull base. Sagittal views are useful

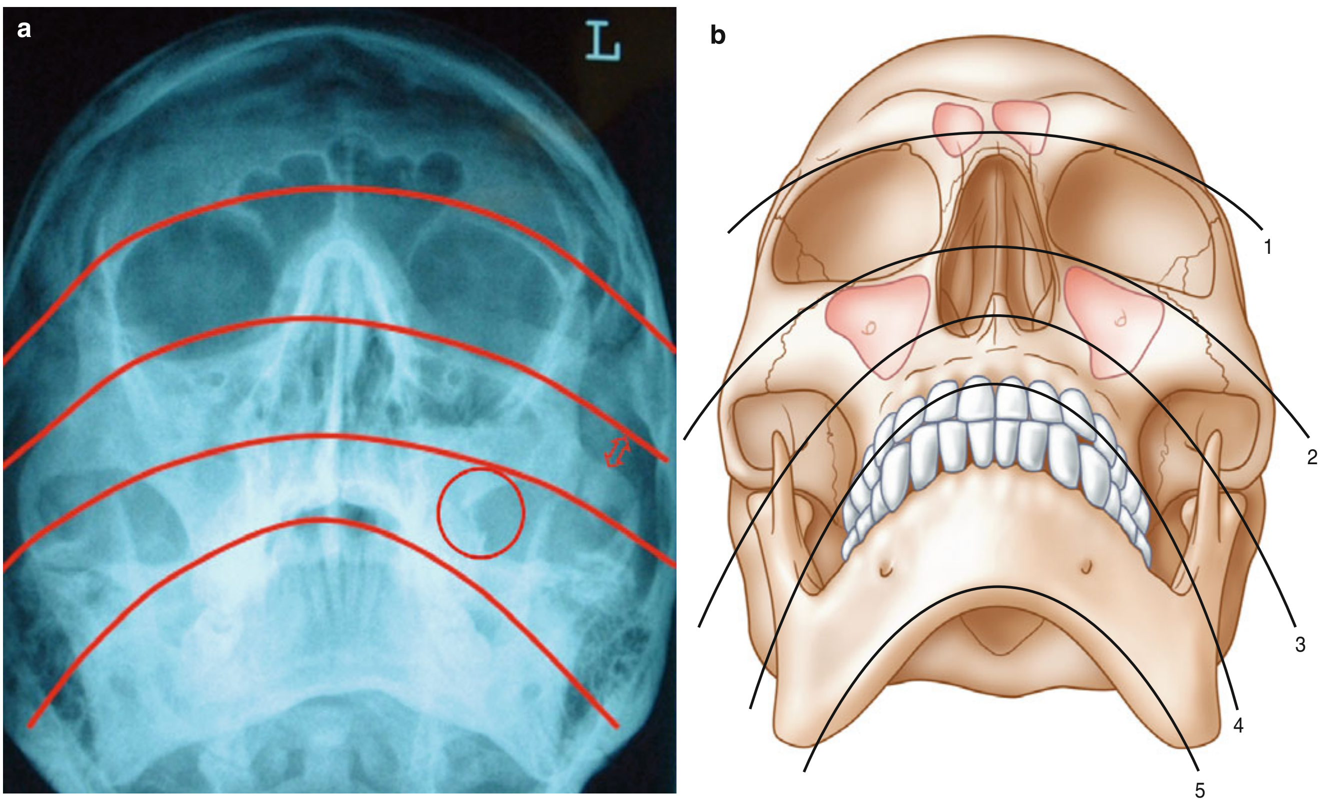

Fig. 8.11 Campbell's lines (*lines*) are a well-known visual aid to assess for steps and asymmetries (**a**, **b**). These are placed along or parallel to the natural boney curvatures seen on the OM views. The displaced fracture of the left zygoma then becomes readily apparent (especially along the arch and buttress in this case)

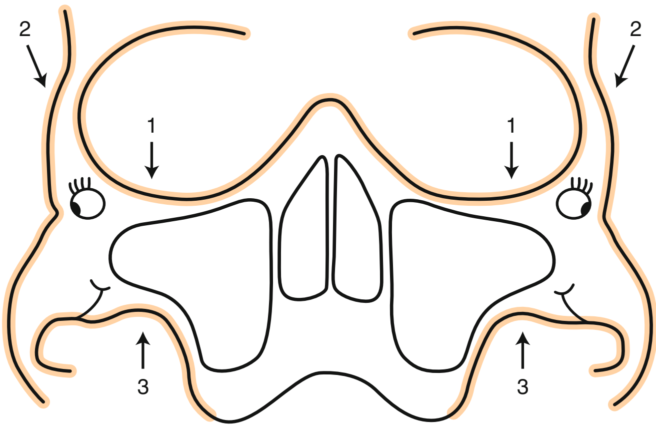

Fig. 8.12 The “baby elephant” interpretation of OM views. Check the sites shown (*1* I.O rim, *2* FZ suture, and *3* Zyg buttress) and watch out for a broken “trunk”!

for assessing the posterior extent of orbital floor fractures and the skull base. Other areas of interest can be visualised by combinations of these three views (see Fig. 8.14).

Today in many centres, three-dimensional reformatting now makes interpretation so much simpler. We can now see at a glance the overall fracture configuration. However, some detail is lost in the reformatting process and conventional slices are still required for detailed assessment (see Fig. 8.15).

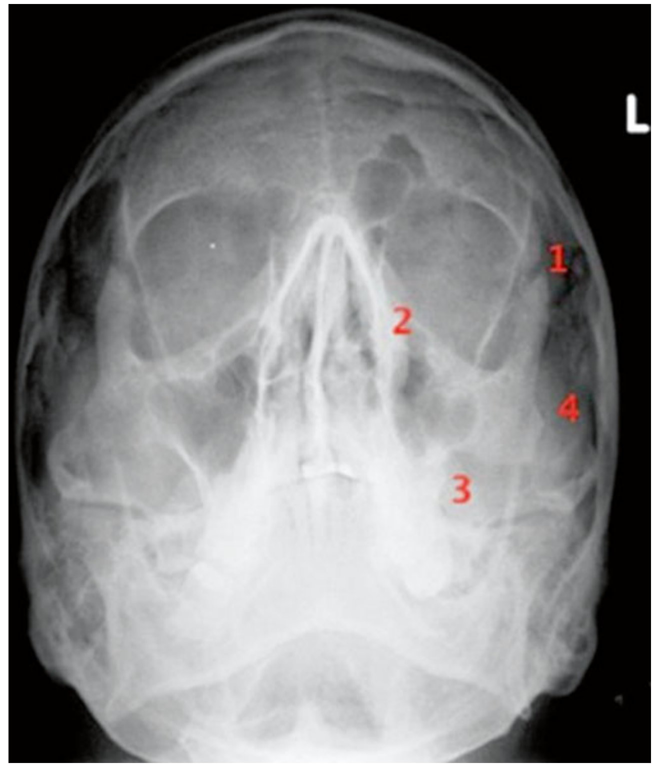

Fig. 8.13 Alternatively, knowledge of a “tetrapod” fracture configuration enables one to inspect the key areas (or “pods”) on an OM view. These are the sites where disruption is most noticeable

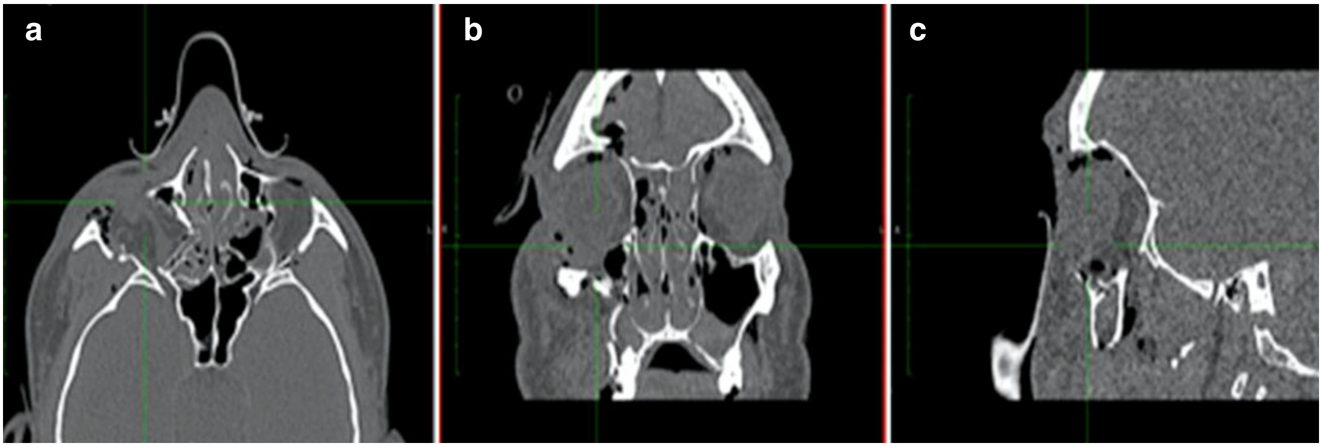

Fig. 8.14 CT assessment starts with visualisation of the scan in the axial plane (**a**). The scans are viewed serially cranial to caudal. This allows accurate assessment of the anteroposterior projection of midface and facial width. Fracture extension into the orbital floor is best assessed in the coronal plane (**b**). Sagittal views define the anterior and posterior margins of the orbital floor injury (**c**). Note the extensive right orbital floor component

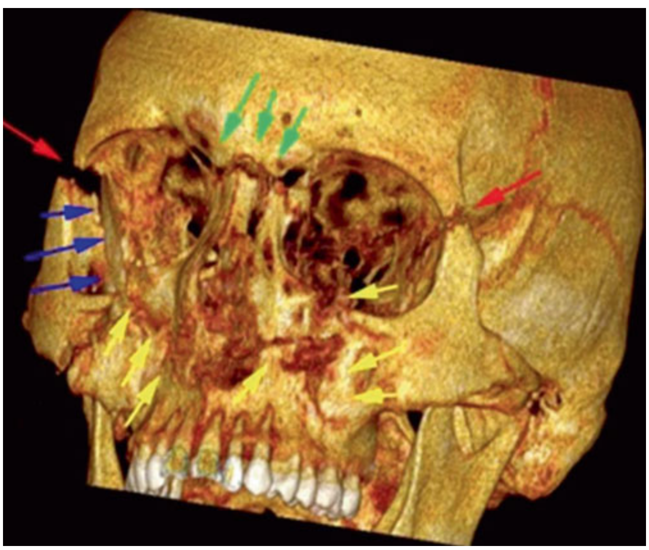

Fig. 8.15 Three-dimensional reformat of CT data. Note the significant distraction of the FZ suture (*red arrows*), the fracture across the infraorbital margins and maxilla at Le Fort I and II levels (*yellow arrows*) and the nasoorbitoethmoid injury (*green arrows*). This is therefore a complex injury, extending beyond the ZMC. The segmented nature of the right zygomatic fracture is illustrated by the distraction at the sphenozygomatic junction (*blue arrows*)

8.4 Management

Patients should be advised not to blow their nose. The concern here is not the surgical emphysema per se, but associated contamination of the orbit and soft tissues. This can result in orbital cellulitis, both a sight and life-threatening condition. With repeated blowing, this can sometimes track down into the mediastinum (see Figs. 8.16, 8.17 and 8.18).

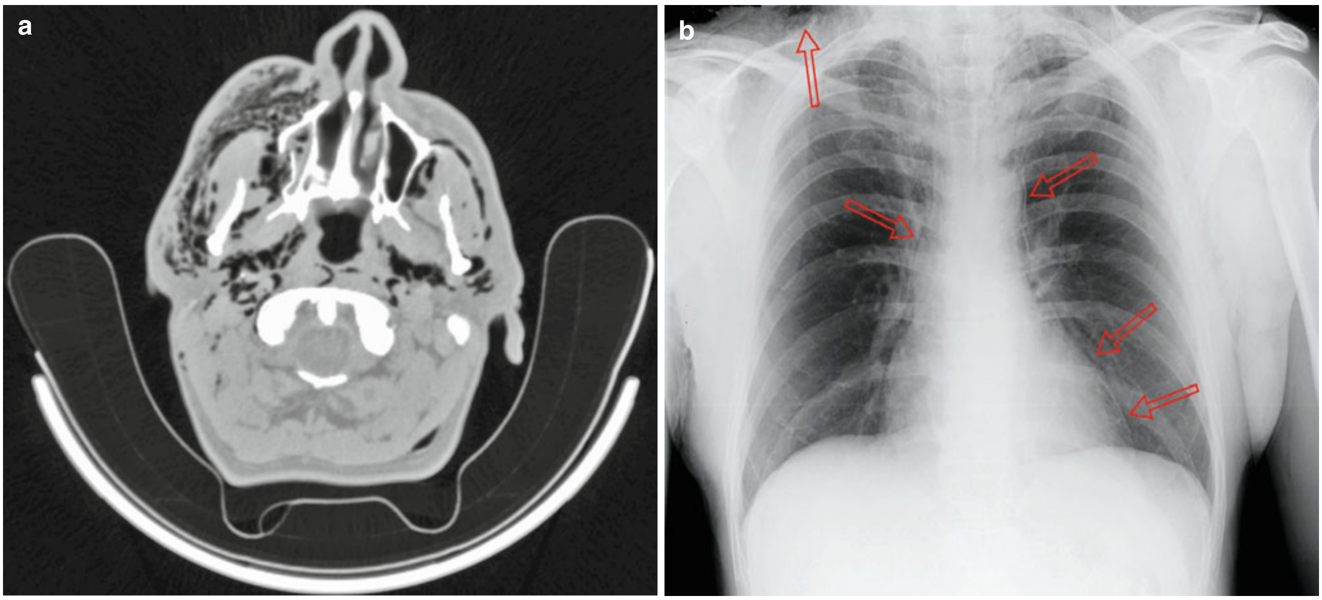

Fig. 8.16 Extensive surgical emphysema in a patient who repeatedly blew their nose following injury. In view of its extent, a chest radiograph was requested. This showed subcutaneous and mediastinal extension with "streaking" and outlining of the pericardium (silhouette sign) (**a**, **b**)

Case 1

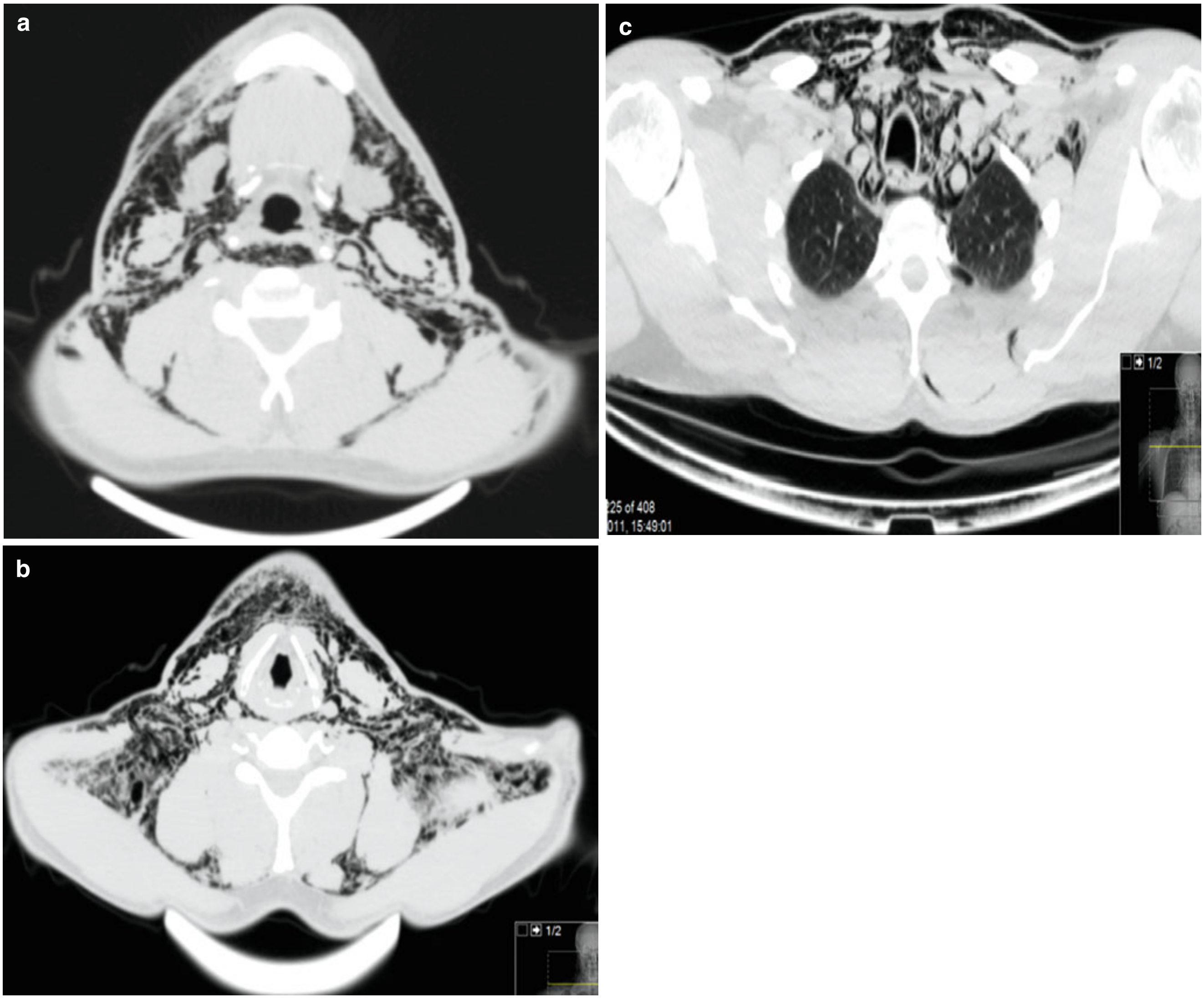

Fig. 8.17 Further CT evaluation of the emphysema demonstrated its full extent (**a**–**c**). Treatment involved antibiotics and refraining from further nose blowing

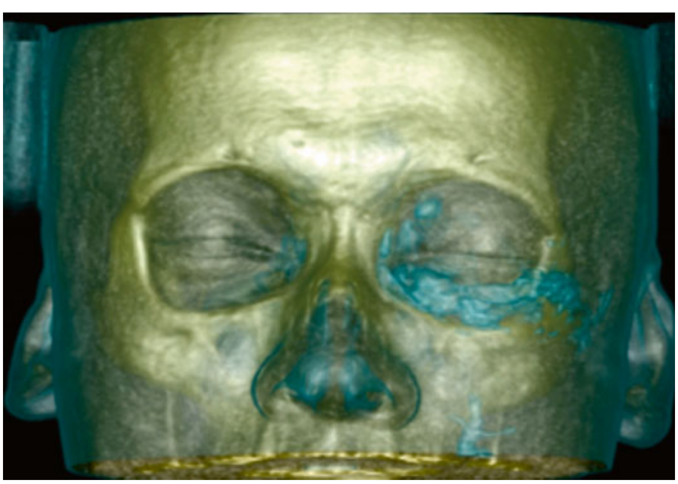

Fig. 8.18 This three-dimensional view shows the presence of subcutaneous air around the left orbit mainly, but also around the left anterior maxilla and right nose. If extensive, this can occasionally lead to an orbital compartment syndrome, requiring sight-saving emergency surgery

8.4.1 Emergency and Initial Management

All blunt periorbital trauma will present with varying degrees of circumorbital bruising and swelling. In most instances, the swelling is preseptal and although it may be impressive, it is seldom sight-threatening. However, if bleeding or swelling occurs behind the septum or behind the globe and it cannot decompress through the fractures, a compartment syndrome phenomenon can develop. This can rapidly result in blindness (see Fig. 8.19 and 8.20).

Patients should initially be advised not to blow their nose, preferably by the referring clinician. Some authorities recommend advising patients not to fly, although how long they should refrain is not known. Three weeks is a commonly used timeframe but some may allow sooner. If there is substantial haematoma, or collection of blood in the sinuses, some surgeons prescribe prophylactic antibiotics. Large superficial haematomas may require drainage.

Fig. 8.19 Extensive chemosis associated with swelling. This is highly suggestive of an incipient raised intraorbital pressure

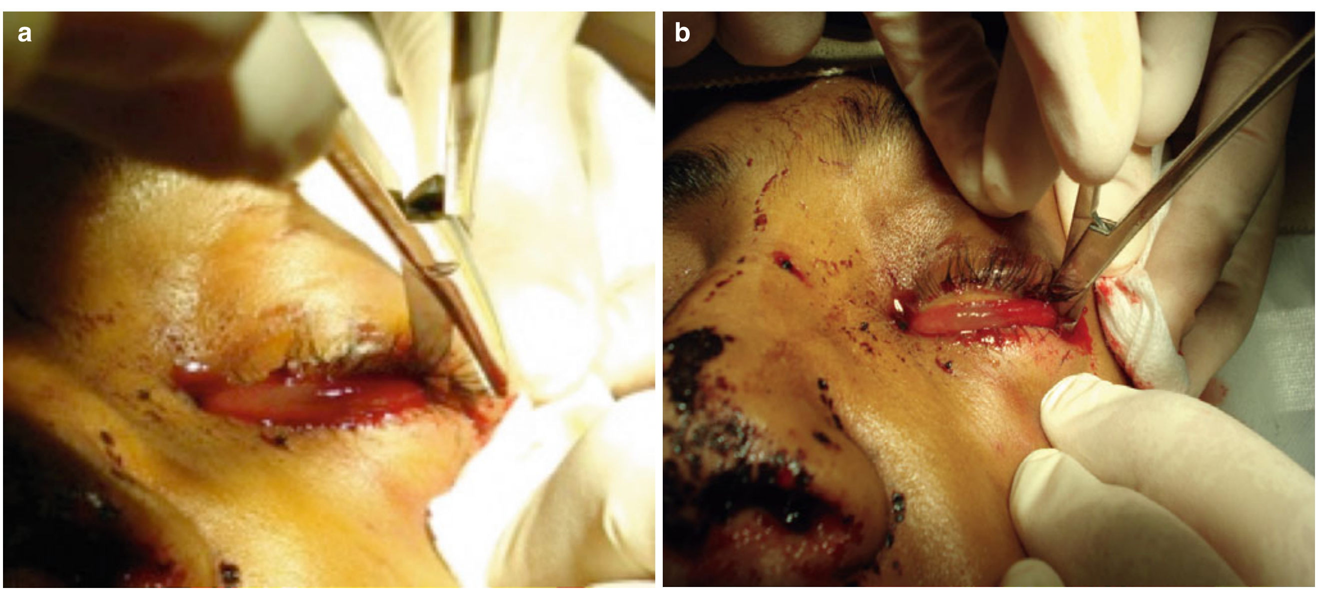

Fig. 8.20 Lateral canthotomy and cantholysis (**a**, **b**). Emergency management of the acutely proptosed eye is discussed elsewhere in this book

8.4.2 Timing of Repair

The vast majority of patients with zygomatic fractures do not require urgent intervention and can be reassessed as outpatients after approximately 1 week. Occasionally circumstances may indicate repair should be undertaken early (within a few days), but this is unusual. The (rare) exception would be in those fractures that have collapsed into the orbit resulting in significant proptosis. This could potentially threaten vision if the orbital pressures become very high or the cornea remains exposed (see Figs. 8.21, 8.22, 8.23, and 8.24).

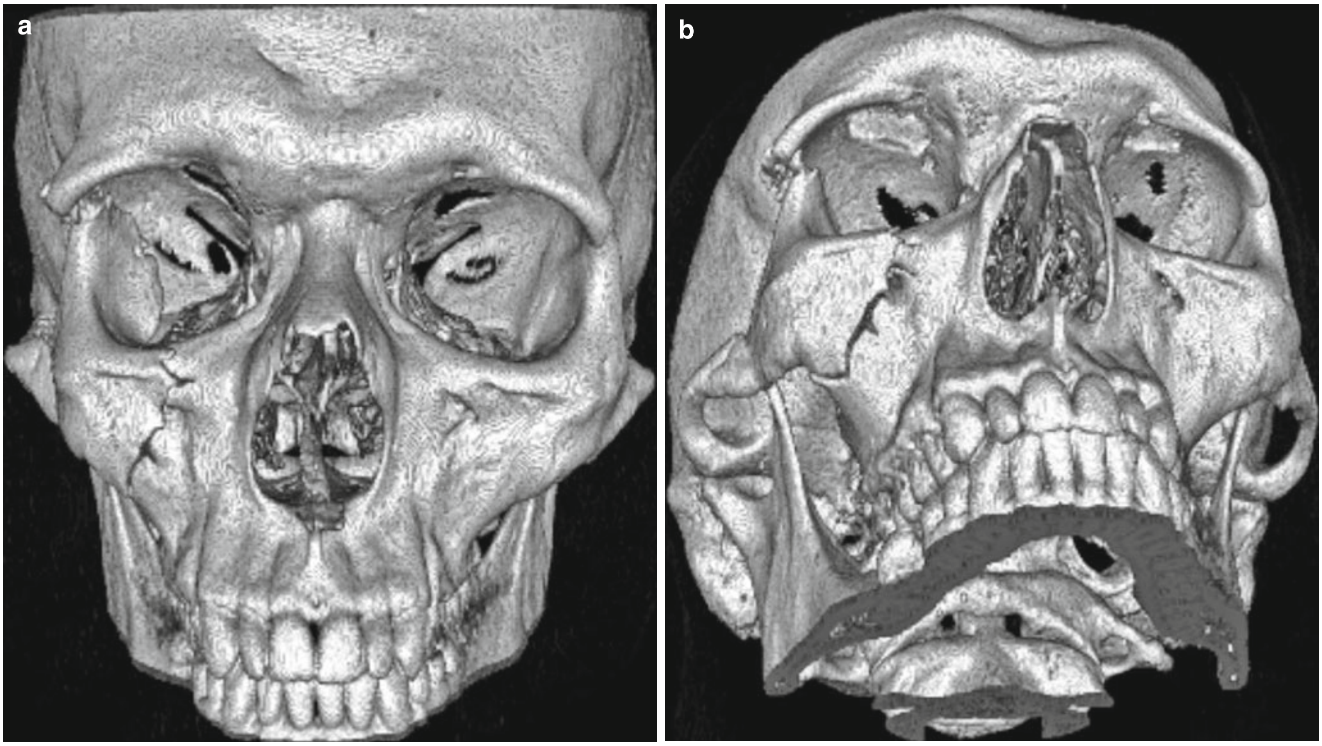

Fig. 8.21 This patient was kicked in the face by a bull. There is medial displacement of the entire ZMC with reduction in orbital volume (**a**, **b**)

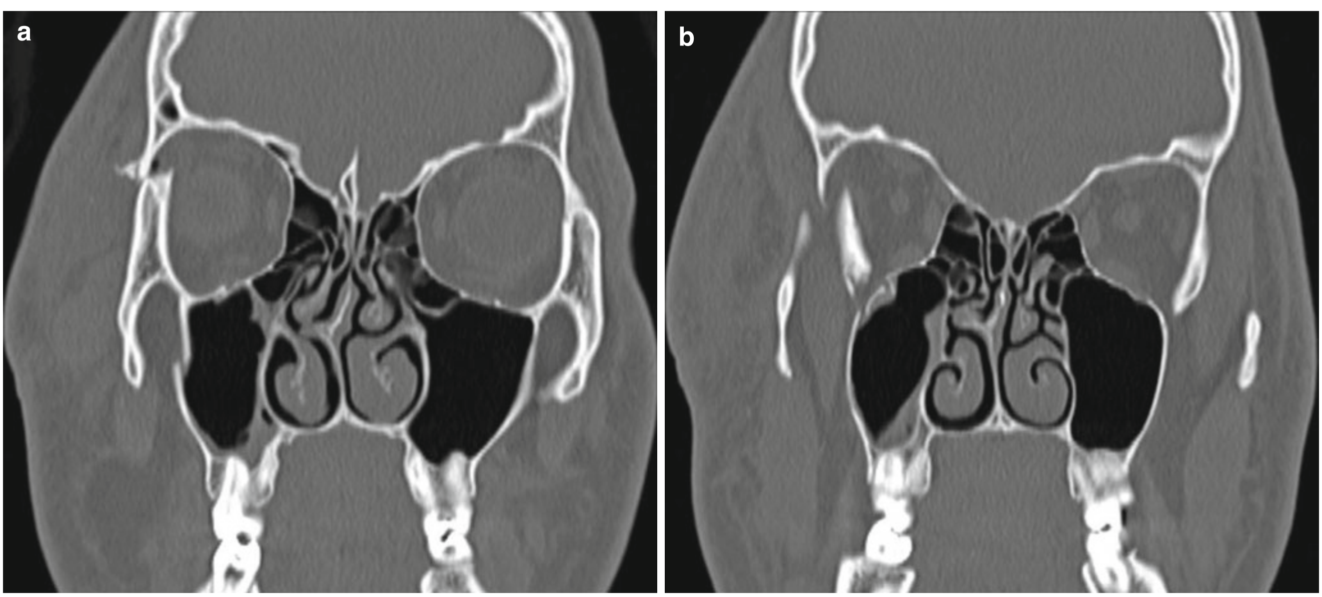

Fig. 8.22 Coronal views clearly demonstrate the severity of displacement (**a**, **b**)

Fig. 8.23 Such cases can result in sight-threatening proptosis. Inability to close the eyelids can also result in drying of the cornea and ulceration

Fig. 8.24 Another example

Otherwise, in most cases surgical treatment may be safely deferred a variable length of time if necessary, depending on the degree of swelling and the general condition of the patient (notably the presence of any head or ocular injuries). Swelling prevents accurate clinical assessment, which is essential not only to determine the need for treatment (do not just look at the radiographs), but also to assess the adequacy of repair during surgery. It also makes placement of cosmetically designed incisions technically difficult, especially around the orbit or eyelids. Furthermore, swelling is usually made worse during and shortly after surgery, and can therefore increase any preoperative proptosis or compartment syndromes (see Fig. 8.25).

Timing is therefore crucial if there is any associated proptosis preoperatively. The optimum time frame for repair is therefore usually between 1 and 2 weeks. Most patients will be suitable for treatment at around 7 days. With delays of 3 weeks or more, outcomes become much less predictable. As the fractures begin to heal there will be areas of osteolysis, granulation tissue, and early callus formation, making precise repair technically more difficult. Fractures that may have initially been stable may subsequently require increased fixation. However, in the authors' experiences acceptable results can still be obtained up to 5 weeks postinjury, but in such cases all the fractures need to be exposed, their callus gently osteotomised and then internally fixed. Delays beyond 5 weeks normally will be at best, very unstable and at worst require formal osteotomy at the fracture margins. Accurate reduction becomes increasingly difficult.

Such delays are not ideal but may be unavoidable in exceptional circumstances. Cases at risk are usually those

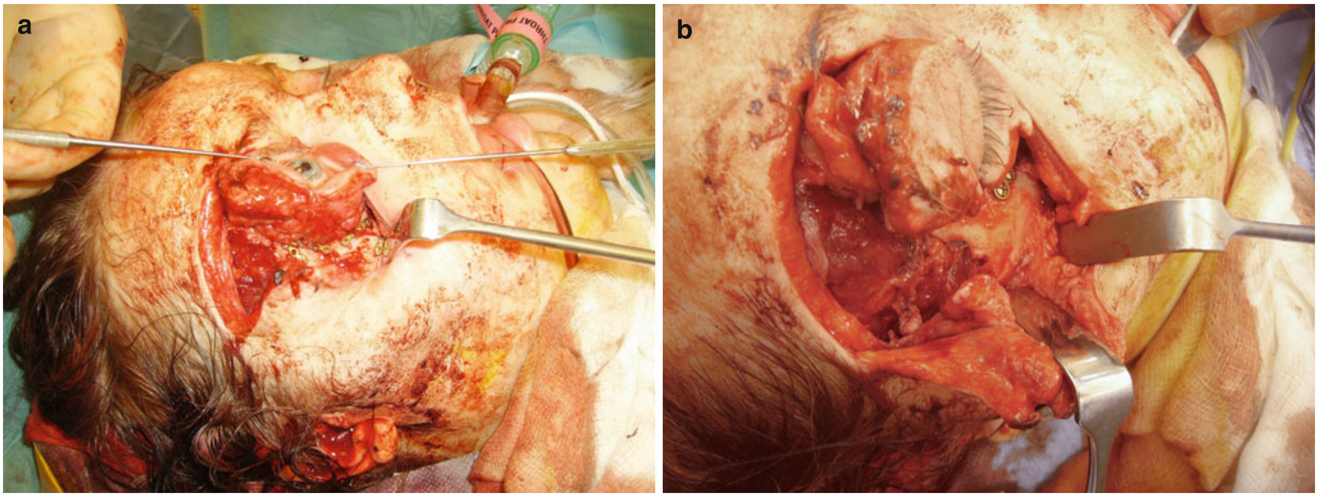

Fig. 8.25 Gross facial and orbital swelling following complex repair of extensive right sided midface fractures (**a**, **b**). Immediate wound closure was not possible and required delayed primary closure—an unusual situation

patients in the intensive care unit (ICU) who require protracted medical support precluding intervention. In these circumstances it is important to communicate early with colleagues and relatives of the patient throughout this period. Delays are often anticipated and in some cases it may be more appropriate to plan for secondary revision surgery, with the agreement of the patient or family.

Conversely, some fractures are best managed with a very brief intervention (if necessarily in the ICU itself), to replace major components of the facial skeleton roughly in the correct position. This is particularly true in patients with associated comminuted nasoorbitoethmoid fractures, for whom broadening of the nose is especially difficult to correct secondarily.

8.4.3 Planning Repair

Indications for repair are shown in Table 8.5.

Table 8.5 Indications for repair of fractured zygoma

Facial deformity
Loss of lower eyelid support
Ocular dystopia
Limitation of mandibular opening
Sensory nerve deficit thought to be caused by nerve compression

The decision *not* to operate is perhaps the most difficult decision of all. If the fracture is minimally displaced, or the patient's tissues are thick and will disguise a fracture (particularly if the patient is older or not concerned with a mild asymmetry), then surgery may be justifiably avoided. This should be documented in the notes. However, given the low risk of modern surgery today, repair can be offered in most fractures.

Following the decision to operate, a surgical plan is then formulated. This can be considered under the method of reduction, points of fixation, and incisions required.

8.4.4 Closed Versus Open Reduction

The merits of closed versus open reduction in general are discussed elsewhere in this book, but to remind us, closed reduction refers to manipulation of a bone without visualisation of the fracture or placement of internal fixation. Whether a fractured zygoma can simply be "lifted," or requires internal fixation, depends on a number of factors. This decision is not always straightforward and different surgeons will opt for a less or a more aggressive approach. Certainly the fracture configuration and the degree of displacement are two important considerations but there are also others (see Table 8.6). CT scanning may be helpful in some cases.

If none of the complicating criteria in Table 8.6 apply, a closed reduction may suffice. Fractures suitable for this method are often those of the zygomatic arch and minimally displaced ZMC injuries without segmentation or comminution. Conceptually, as the bone is reduced, the fracture margins interdigitate, providing support. It therefore stands to reason that if this “meshing” of the fracture is not possible, or if the periosteum is severely torn, it will be unstable. Fractures must also be treated early, i.e., within 2 weeks, when stability is more likely (see Figs. 8.26–8.33).

Case selection is therefore very important both preoperatively and “on the table,” to identify those patients in whom the fracture is at risk of collapsing postoperatively if it is not plated. Once lifted, some surgeons gently press on the cheek prominence to see it if it will remain in place. Although a very imprecise test, this seems to work in experienced hands.

Closed reduction techniques include:

- Temporal approach (Gillies lift)
- Percutaneous or “Malar” hook (sometimes referred to as “Poswillo”)
- Eyebrow approach (zygomatic elevator)
- Carroll-Girard screw (now more of historical importance)
- Intraoral approaches (upper buccal sulcus)

All of these involve making a small incision somewhere on the patient and can therefore be considered, technically, as open techniques.

Table 8.6 Choosing method of repair

Consider the following:
How displaced is the fracture? Accept if minimal, to avoid risks of surgery (especially in the medically compromised, or elderly and those on aspirin/anticoagulants)
Does the lateral buttress look comminuted on imaging? If so, some sort of fixation may be required to prevent collapse of the cheek. Caution with percutaneous hooks placed blindly—they may comminute the fracture site further.
Is the zygomatic arch “**greensticked**” **or telescoped**? The arch is important for cheek projection and needs to be reduced and aligned fully to maintain this support. If telescoped, access to it for fixation may be required.
Is the infraorbital rim comminuted? If so it may need repair.
Does the orbital floor need exploration and/or repair as well? (see Chap. 9)
Is the FZ suture “**greensticked**,” **or displaced**? If displaced this may need open reduction and repair.

Fig. 8.26 This fracture has rotated around a vertical axis as shown. It is a good case for closed reduction

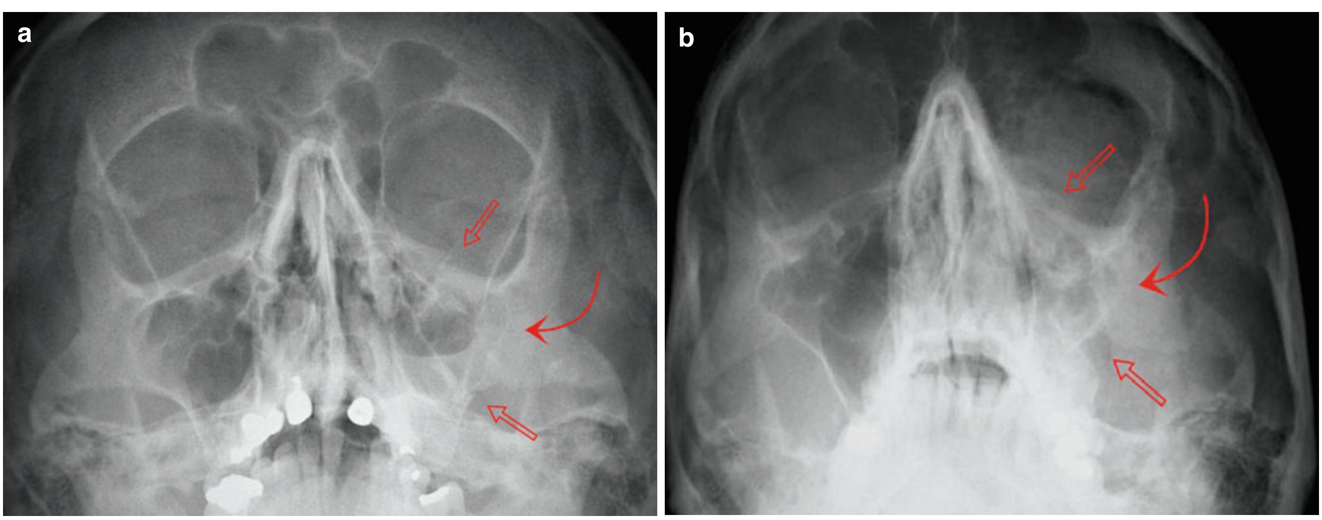

Fig. 8.27 In these two cases (**a**, **b**), the fractures have “hinged” medially across their respective FZ sutures. The buttresses are stepped but will be attached to the periosteum. Closed reduction could be attempted, but fixation may be required

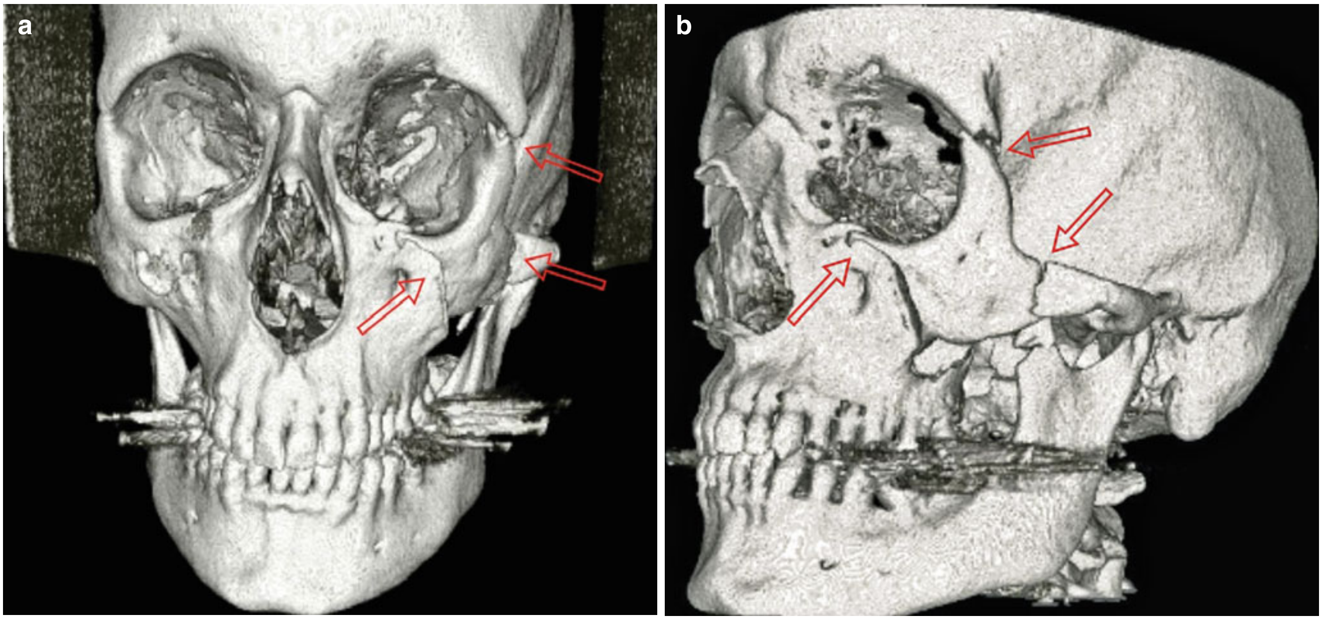

Fig. 8.28 Medial rotation of the ZMC with gross displacement of the FZ suture (**a**, **b**). This will almost certainly require fixation

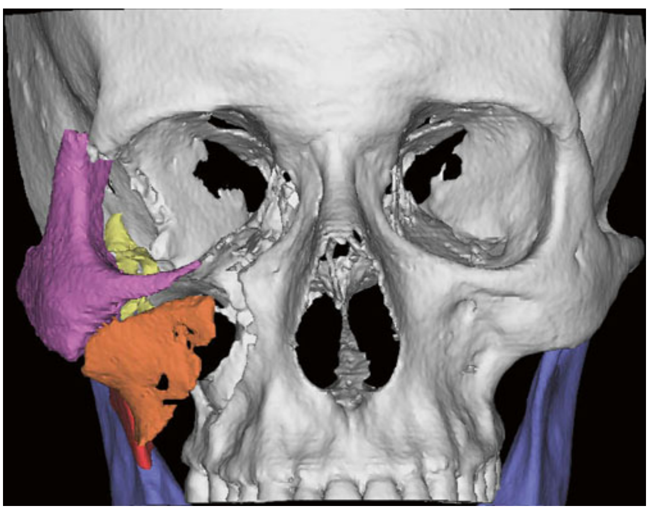

Fig. 8.29 Comminuted fracture of the right zygoma with lateral displacement. Note significant defect of the lateral orbital wall

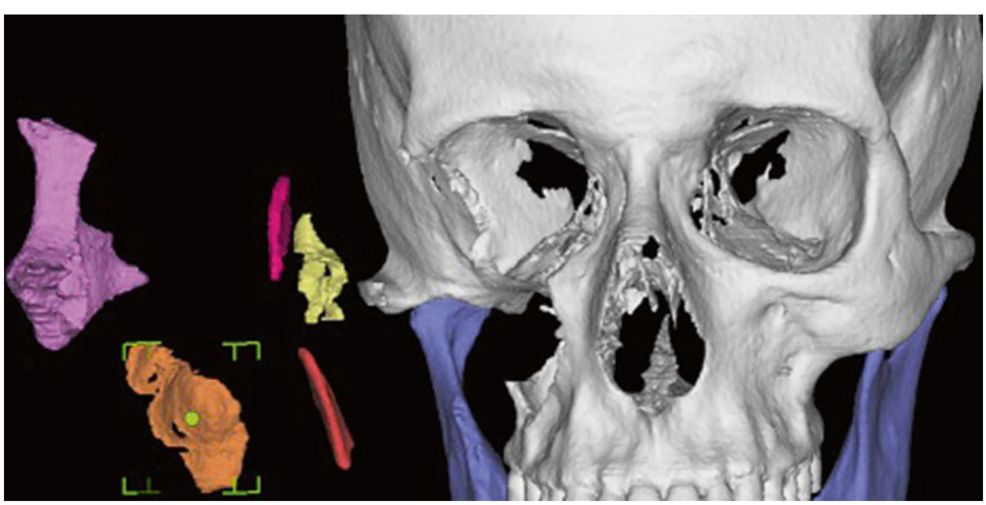

Fig. 8.30 Disarticulation of the fracture complex to determine access, sites of fixation, and reconstruction

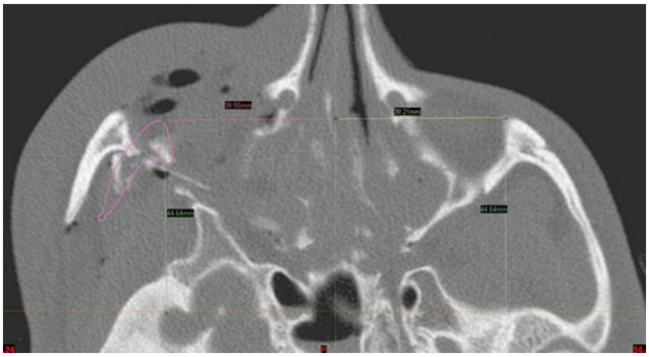

Fig. 8.31 Using "mirror" techniques, the amount of displacement can be appreciated

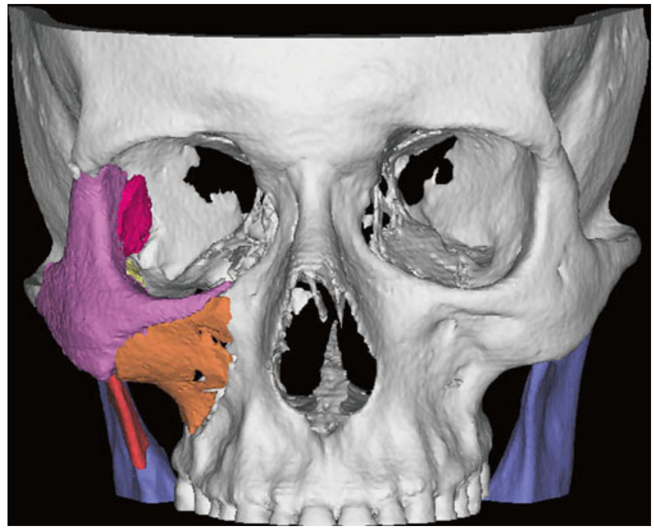

Fig. 8.32 Reconstituted complex on CT, with reconstruction of lateral orbital floor and lateral wall

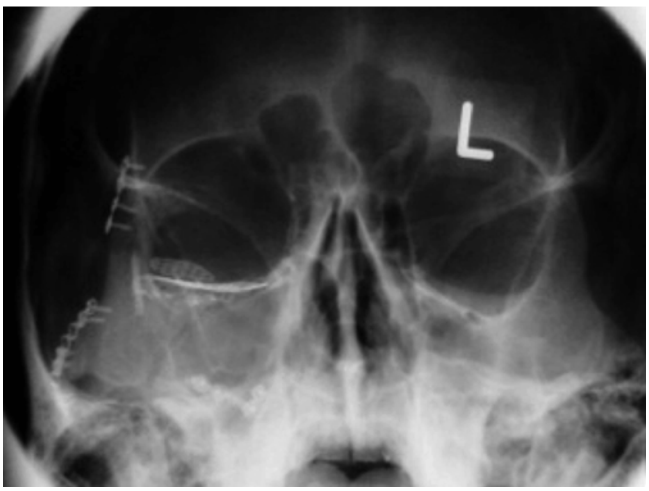

Fig. 8.33 Postoperative film

Fig. 8.34 Bristow elevator (*left*), "Kilner" (*centre*), and Rowe elevator (*right*) for Gillies lift

8.4.4.1 Gillies Lift

The Gillies lift is a versatile procedure commonly used to elevate fractures of the zygoma or isolated depressed arch fractures, often with very predictable control. The principle is simple. The temporalis fascia is a thick, relatively unyielding layer that covers the temporalis muscle. It passes inferiorly and is attached to the zygomatic arch and frontal process of the zygoma. Therefore, any instrument passed inferiorly, deep to this layer will automatically pass underneath these bones and can therefore be used to elevate them. A number of purpose-made instruments have been designed for this (see Fig. 8.34).

This technique may be used in fractures of the arch and the body. Once placed, the elevator also facilitates three-

dimensional control of the body, which can be adjusted in both the transverse and anteroposterior plane. However, the elevator should be placed with care and positioned away from areas of comminution. These could displace further during elevation.

This technique has the added advantage of allowing the fracture to be controlled at a site distant from where bone is to be plated. Support can be carried out by a second operator, allowing the bone to be held in position while fixation is applied. This procedure is rapid and of low morbidity. There are very few disadvantages. In patients with alopecia, an intraoral approach may be preferred.

A full-thickness skin incision is made in the hair-bearing scalp of the temple at 90° to the orientation of the elevator and parallel to the hair follicles. Considerable scope is possible in placement of this incision. Blunt dissection then exposes the temporalis fascia. This can be done simply and quickly using a couple of curved clips. Very often the superficial temporal artery is encountered and may need to be cauterised or ligated. The temporalis fascia is a thick layer and is usually very easily identified (see Figs. 8.35, 8.36 and 8.37).

A second incision is then made through the fascia, parallel to the skin incision. As this incision is made, the underlying temporalis muscle often begins to bulge through the gap in the fascia and care must be taken not to cut into it as well. Using a small curved clip, the lower edge of the fascial incision is identified and grasped. This is a key part of the procedure, as it is essential to ensure that the elevator passes beneath the temporalis fascia and not superficial to it (see Figs. 8.38 and 8.39). Lifting an incorrectly placed elevator will stretch the overlying soft tissues and can result in traction injury to the facial nerve.

Once the lower edge of the fascial incision has been clearly identified, the elevator can be passed. Sometimes it may be easier to initially pass a smaller elevator such as a Howarths periosteal elevator. This is then replaced by the larger definitive elevator. It is important to ensure that the tip of the elevator passes underneath the arch/body of the zygoma. This can often be felt by the operator as the handle of the elevator is deflected as the tip passes under the bone (see Figs. 8.40, 8.41, 8.42 and 8.43).

Some elevators are V shaped, with an external component that not only provides grip for the elevation process, but also indicates where the tip of the deeper component is.

The fracture is then elevated. This is also a key part of the procedure. Depending on the elevator used, it is gripped with one or two hands and then lifted, NOT levered. It is important not to use the skull as a fulcrum—this could result in a fracture. In most cases, successful fracture reduction is easily recognised, when the depressed fragments are heard, or felt to "click" back into position (see Figs. 8.44, 8.45 and 8.46).

The success of this technique relies in part on the fact that the periosteum enveloping the fractures remains largely intact. Intrinsic stability of any reduced fracture requires intact periosteum and successful interlocking ("meshing") of the fragments. This technique therefore works best with isolated and simple depressed fractures of the arch, which has resulted in a "V- shaped" depressed fracture, or "en bloc" fractures of the ZMC without comminution.

Once reduced, the fracture sites may then be palpated or observed directly (if incisions for fixation have been made), to check the adequacy of reduction. If multiple sites have been exposed, the reduction should be judged at each of these to verify the correct position.

Following reduction, the Howarth elevator may then be reintroduced and passed along the inside surface of the arch to assess for adequacy of alignment. Some authorities recommend using the elevator to "smooth out" the undersurface of the arch once it has been elevated. Care is required with this part of the procedure. Overzealous "smoothing" can result in over-reduction and bowing of the arch, with an increase in transverse facial width.

Following removal of the elevator, the temporal incision can be closed. The underlying temporalis fascia incision does not need to be closed. A forced duction test should also be undertaken. Rarely, reduction of the orbital floor can trap herniated orbital contents that may not have been trapped preoperatively. This can result in postoperative diplopia, entrapment, and the embarrassing need to return to theatre. If identified at the time of surgery, orbital floor exploration is indicated. All patients should therefore be consented for orbital exploration.

Gillies Lift: Transverse Incision

Case 1

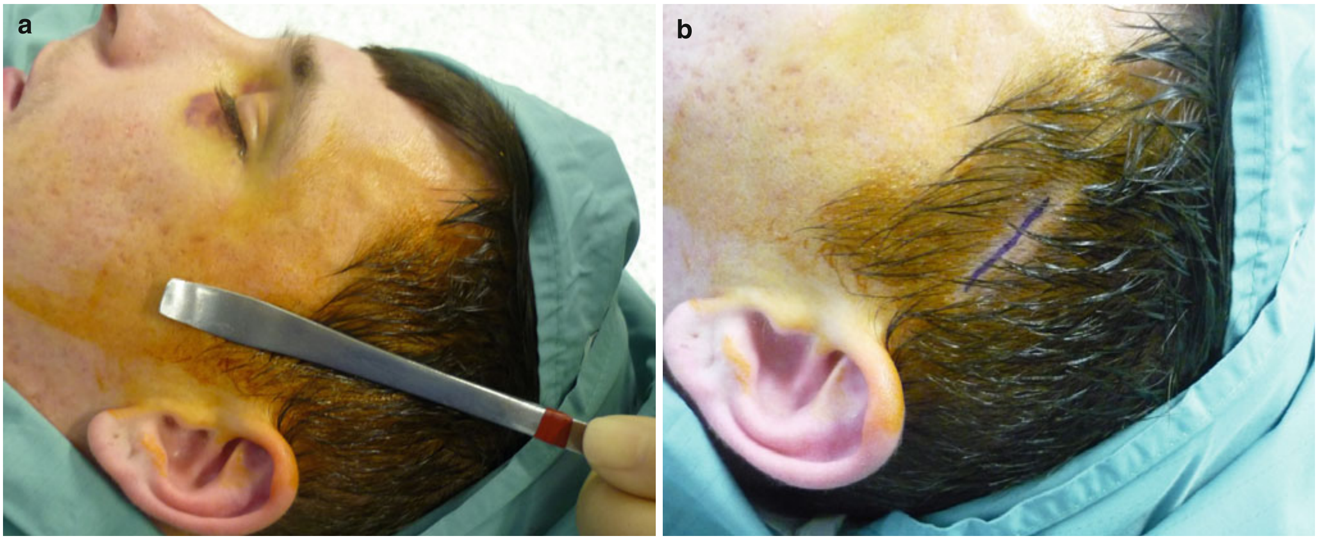

Fig. 8.35 Initial elevator orientation (**a**) and skin marking (**b**) (see text for detail). The surface marking is approximately 2 cm above the root of the ear at 45°. The incision is usually around 2 cm long

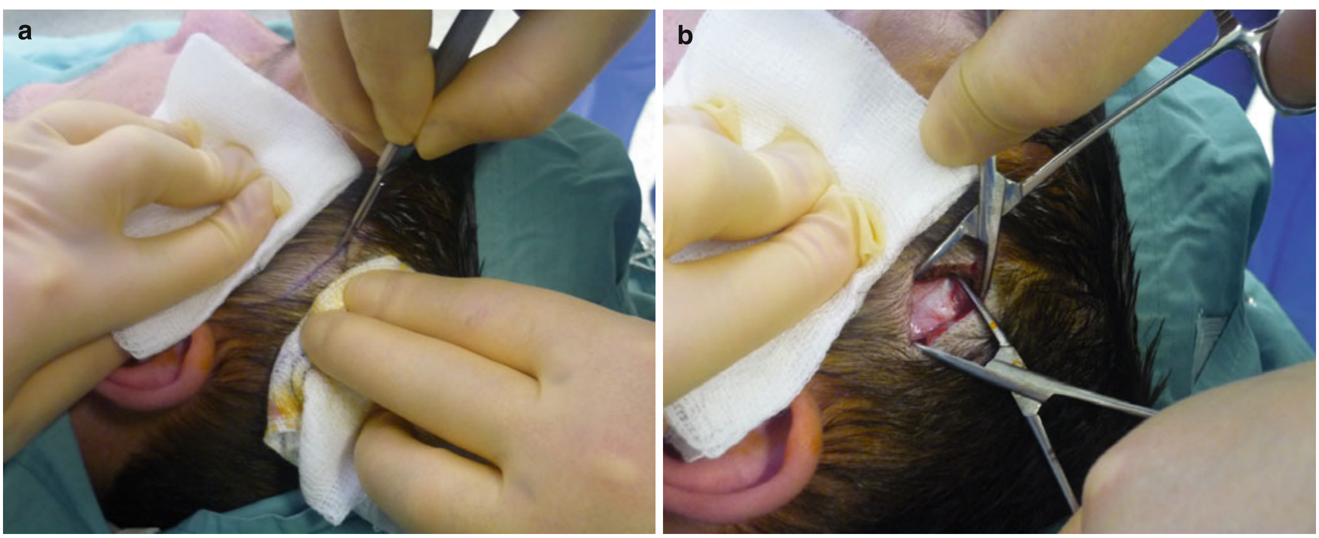

Fig. 8.36 Following injection of local anaesthetic into the scalp, an incision is made through the skin (**a**). This is followed by blunt dissection onto and exposing the temporalis fascia (**b**)

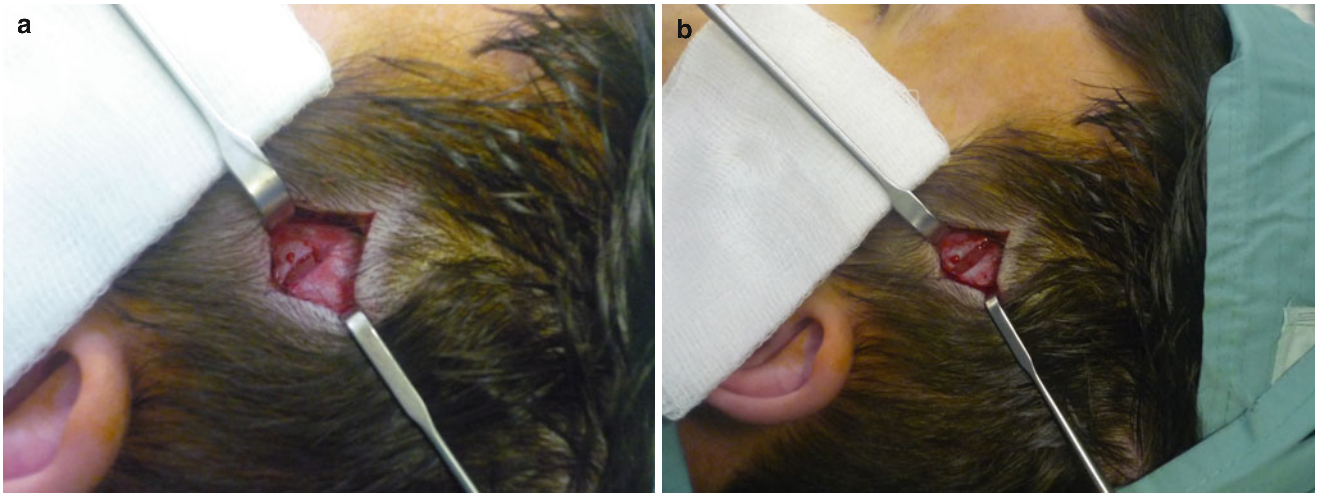

Fig. 8.37 Temporalis fascia incised (**a**, **b**)

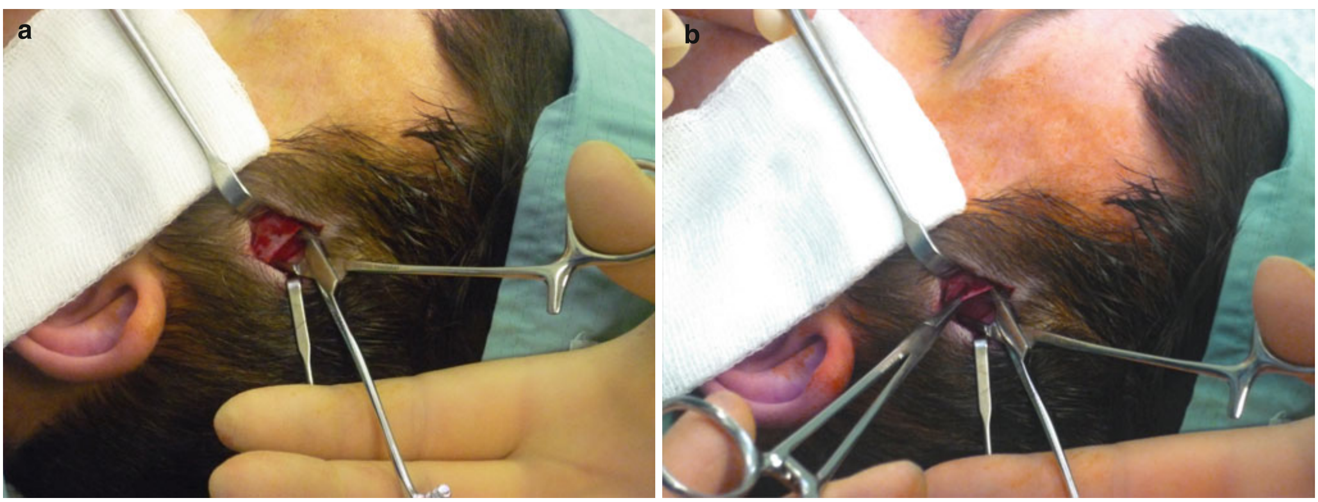

Fig. 8.38 Identification of the plane deep to the fascia, above the muscle (**a**, **b**). This is a key part of the procedure. Identification of the correct plane is essential

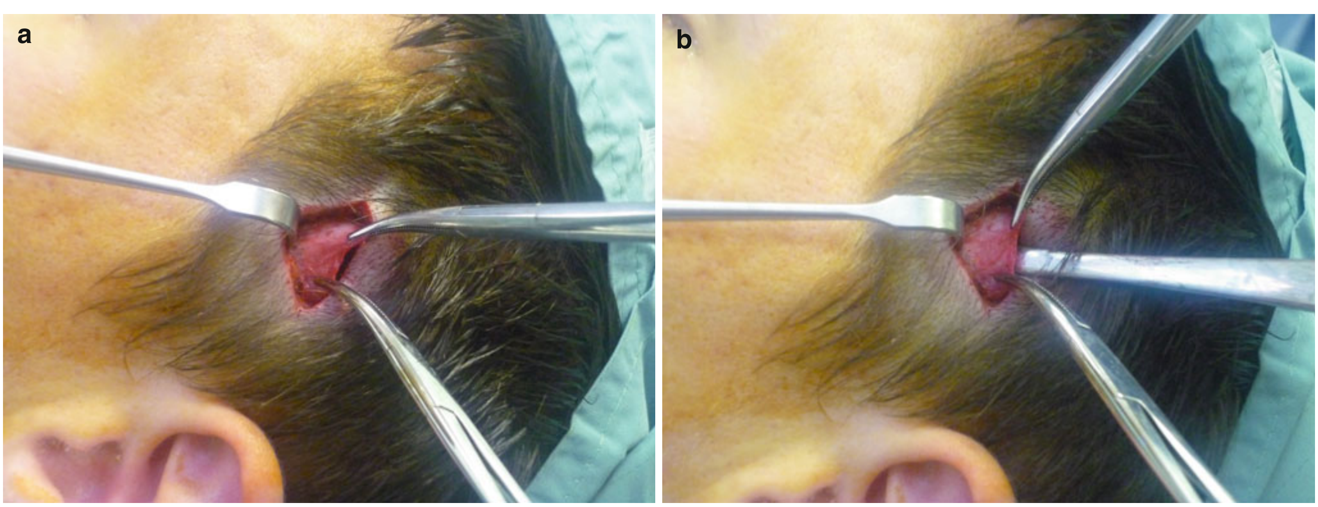

Fig. 8.39 The lower flap is supported with clips (**a**) and a Howarth periosteal elevator passed deep to the fascia (**b**)

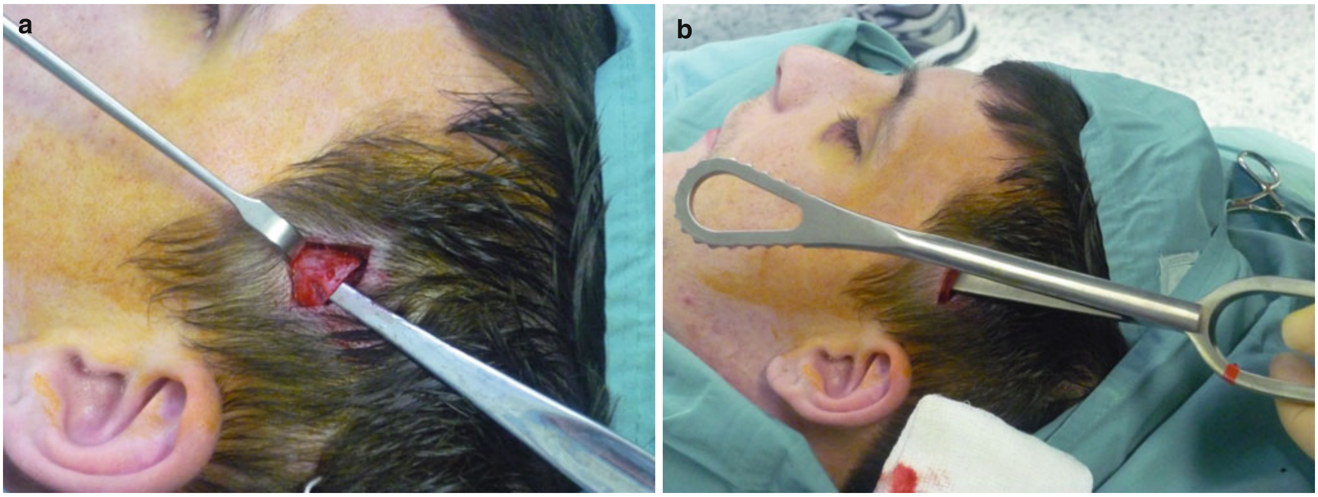

Fig. 8.40 Passing the Howarth first is a useful way to define the correct plane (**a**). It can then be easily replaced by the definitive elevator (Rowe in this case) (**b**)

Fig. 8.41 Model illustrating passage of elevator deep to temporalis fascia. It is passed under the arch and posterior ledge of the zygomatic prominence

Fig. 8.42 It is very important not to place the elevator in the incorrect plane. To ensure a safe placement, the elevator can be passed deep to the Howarth. This safeguards against misplacement

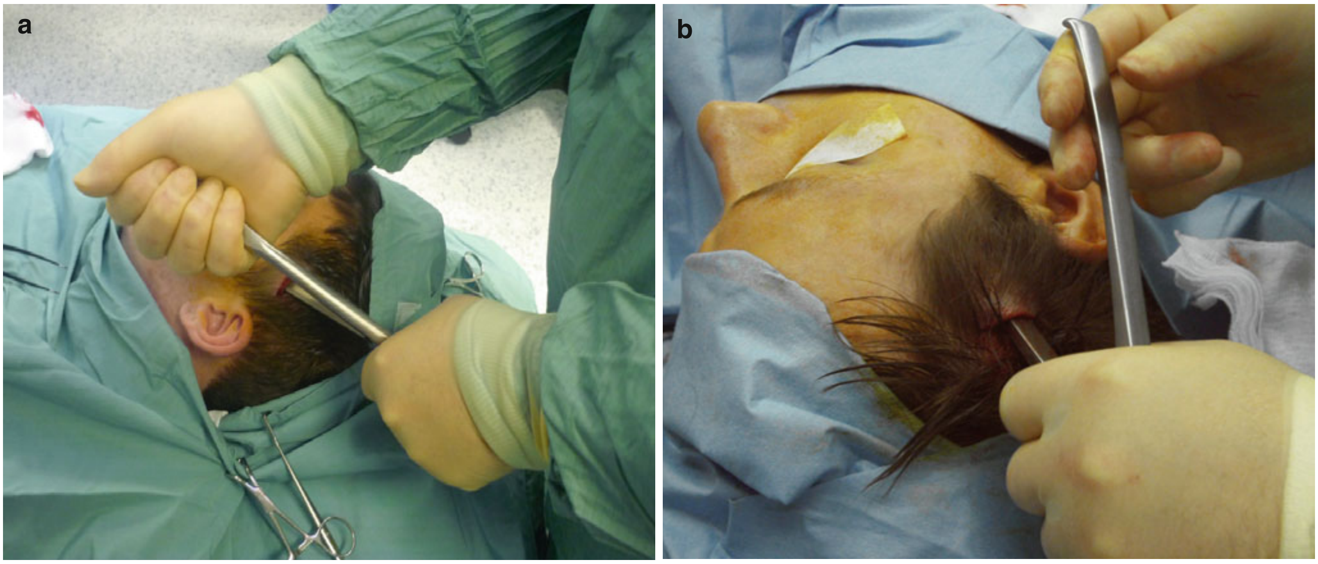

Fig. 8.43 While an assistant steadies the head, the elevator is lifted, not levered, against the skull (**a**). Elevation of the bone should mirror the opposite of the displacing force. Sometimes the bone may need to be "steered" around any impacted parts (particularly at the FZ suture) (**b**)

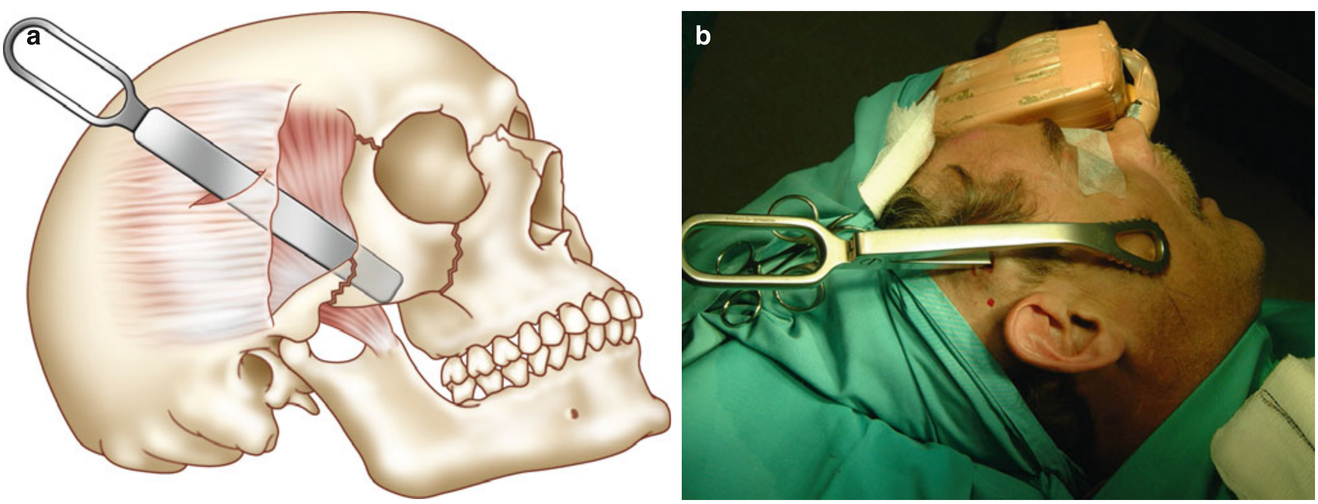

Fig. 8.44 Correct positioning of the tip of the elevator prior to lifting (**a**, **b**)

Fig. 8.45 Some elevators have an external limb that indicates the position of the tip

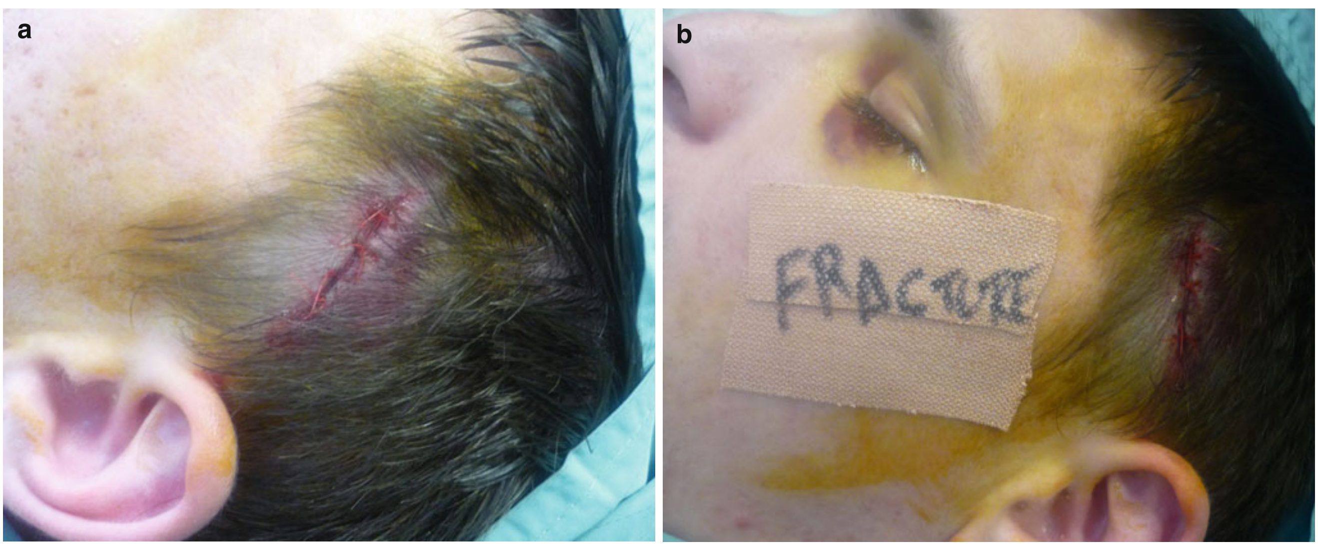

Fig. 8.46 Following wound closure (**a**), mark the surgical site (**b**). Do not draw on the skin—someone may try to rub it off and displace the fracture!

Case 2

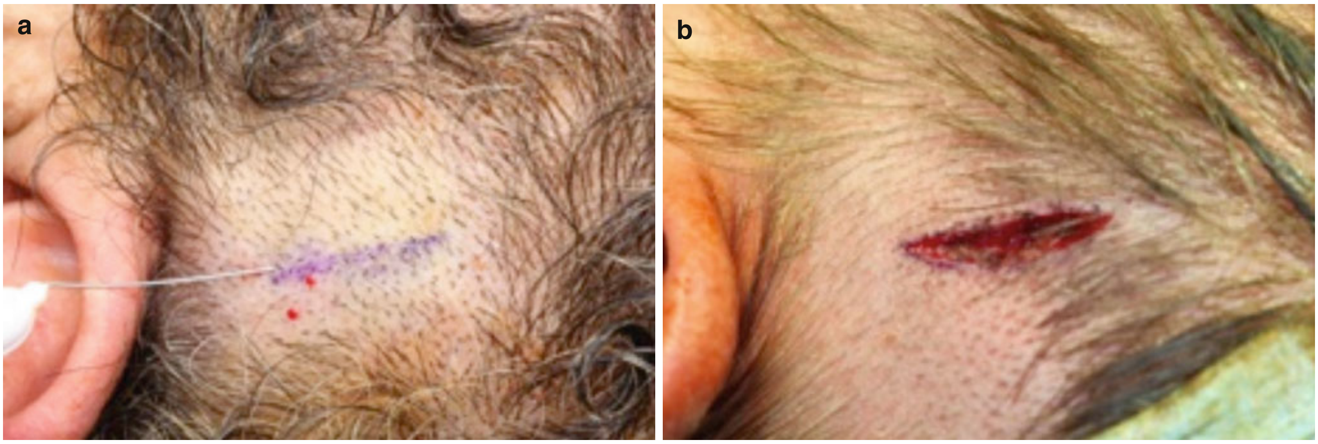

Fig. 8.47 This follows the same sequence as case 1 (**a**, **b**)

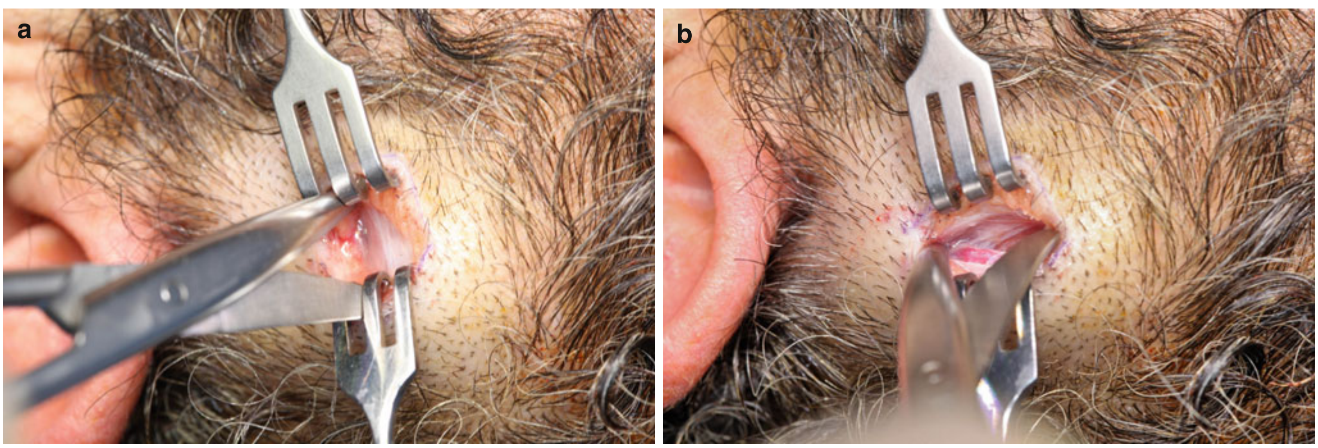

Fig. 8.48 Initial dissection (**a**, **b**)

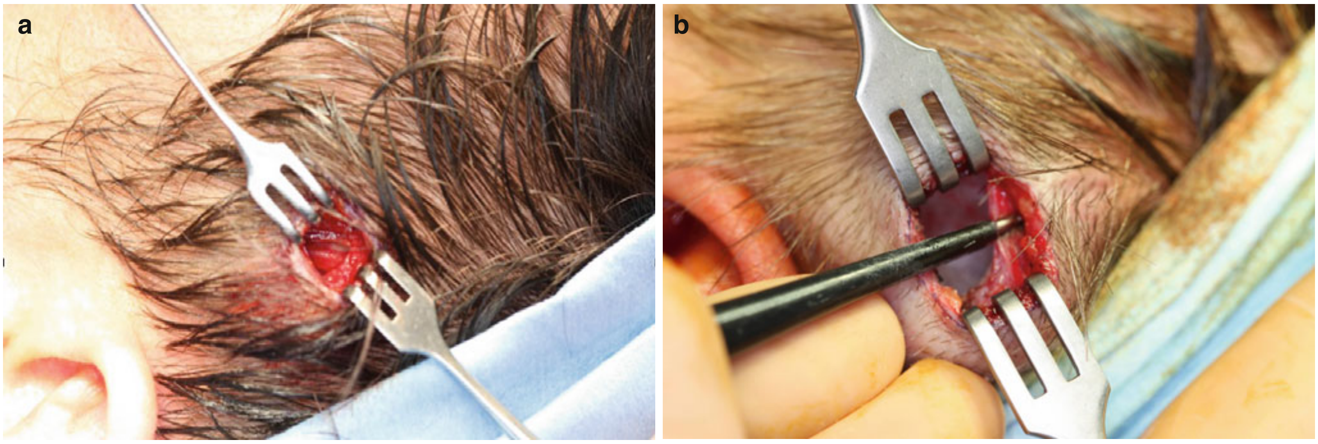

Fig. 8.49 The superficial temporal artery is frequently encountered (**a**). This can be ligated or cauterised (**b**)

Fig. 8.50 Temporalis fascia incised

Fig. 8.51 Passage of Howarth's elevator (**a**, **b**)

Fig. 8.52 Positioning (**a**) and elevation (**b**)

Fig. 8.53 Closure with Vicryl

Case 3

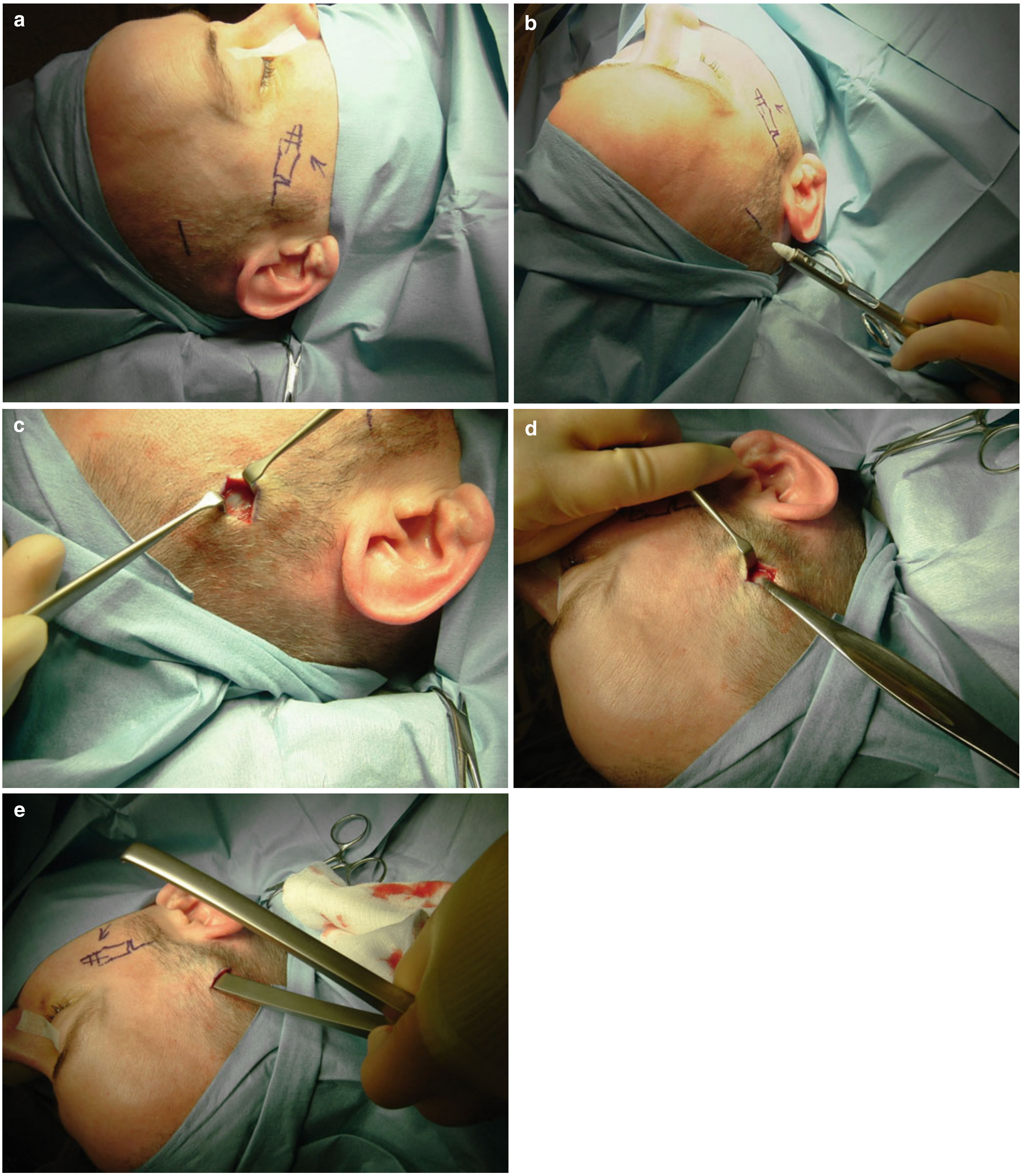

Fig. 8.54 (**a**–**e**) This follows the same sequence as case 1

Case 4

Sequence as previously described for cases 1 and 2.

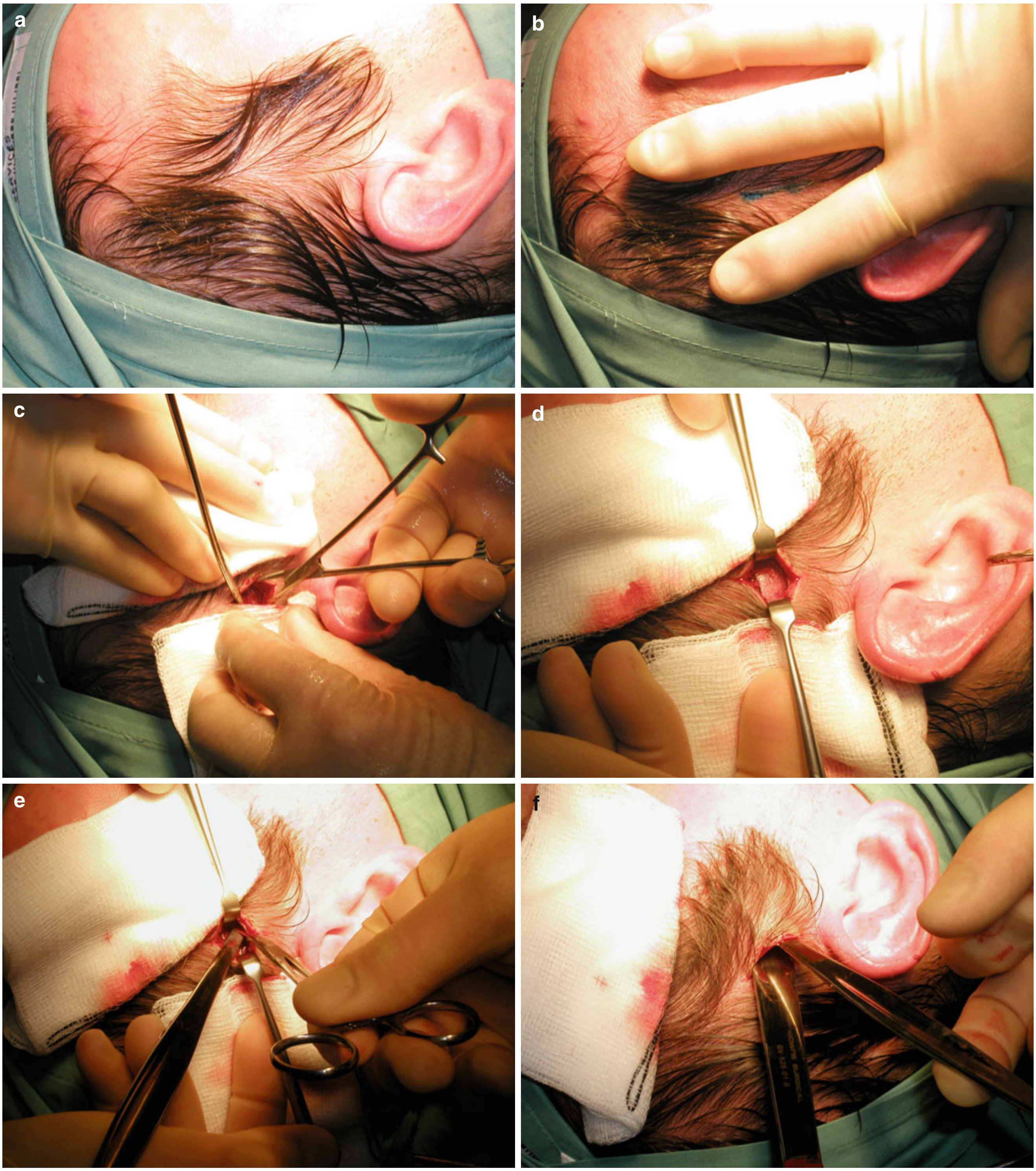

Fig. 8.55 (**a**–**h**) Gillies lift: an alternative incision. This follows precisely the same sequence as the preceding cases. However, the incision is at 90° to the others. In some patients this may be preferable depending on the arrangement of the hair

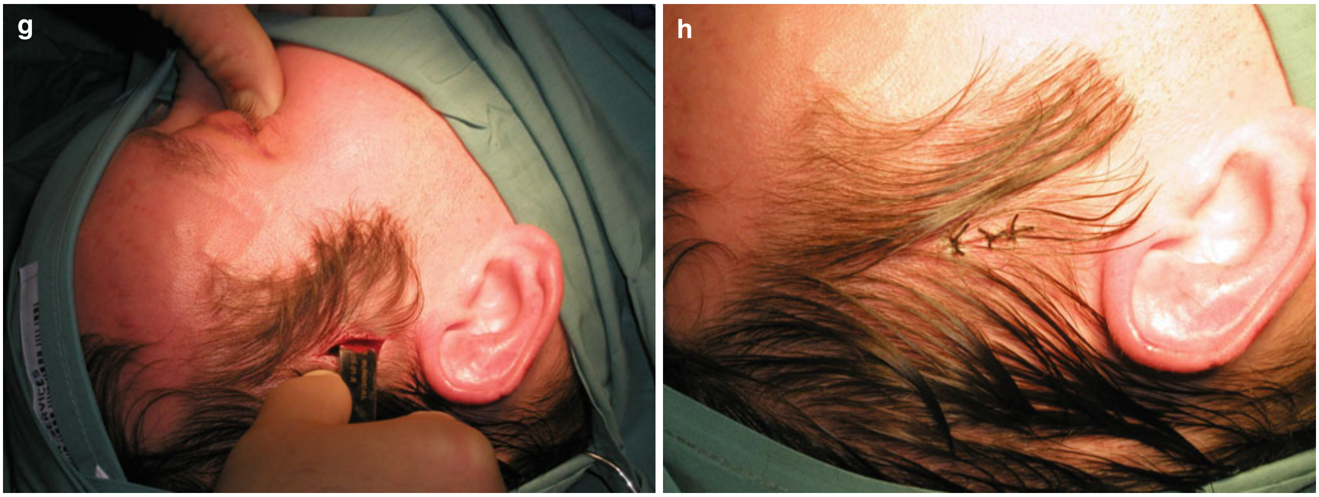

Fig. 8.55 (continued)

8.4.4.2 The Malar Hook (Poswillo Hook)

The malar hook technique is a very quick way of elevating a depressed fracture of the zygoma, through a percutaneous stab incision on the cheek. It can also be used to elevate the bone through a transoral incision, prior to osteosynthesis. Its advantage lies in the speed in which elevation can be achieved and its minimalistic approach. However, the stability of this closed reduction technique relies entirely on the precise reduction and locking together of the fracture fragments as previously described. Therefore, this technique works best in simple "hinged" fractures, rather than those which are comminuted, or have separation at the FZ suture.

This procedure involves making a stab incision in the skin of the cheek through which the hook is passed. The tip then engages the undersurface of the prominence of the zygomatic buttress. Fracture comminution in the zygomatic body and buttress are therefore relative contraindications, although they are not absolute. Percutaneous placement is very well tolerated and the small stab incision usually heals very well.

The precise placement of the skin incision is not crucial because of the mobility of the skin in this region. However, its approximate site is determined by the intersection of two lines, a horizontal line extending from the base of the nose and a vertical line dropped from the lateral canthus, as shown. At this point a small stab incision is made using a scalpel blade. This only needs to be long enough to pass the hook. It should be orientated in a suitable skin crease or relaxed skin tension line. The tip of the hook is then passed through the incision and gently guided under the prominence of the zygomatic bone. It is essential to ensure that the hook is fully engaged before attempting to lift the bone, otherwise significant damage to the overlying soft tissues can occur.

The head is stabilised by an assistant and the cheek then elevated. The direction of pull is upwards and laterally at about 45° as shown. Successful elevation is usually felt easily. However, this is no guarantee of stability. The hook should then be removed and the cheek assessed for position and stability. Following elevation, a single skin suture is usually enough to close the stab wound (see Figs. 8.56–8.61).

Whether the hook is used in isolation or followed by internal fixation is a matter of personal preference. However, if it has been determined preoperatively that a buttress plate will be required, the hook (or an elevator) can be passed through the intraoral incision, rather than making a skin incision. Alternatively, a small Langenbeck retractor may be used to elevate the fracture. This approach does lend itself well in anteroposterior displacements. Choice of instrumentation is a matter of personal preference (see Figs. 8.62, 8.63, and 8.64).

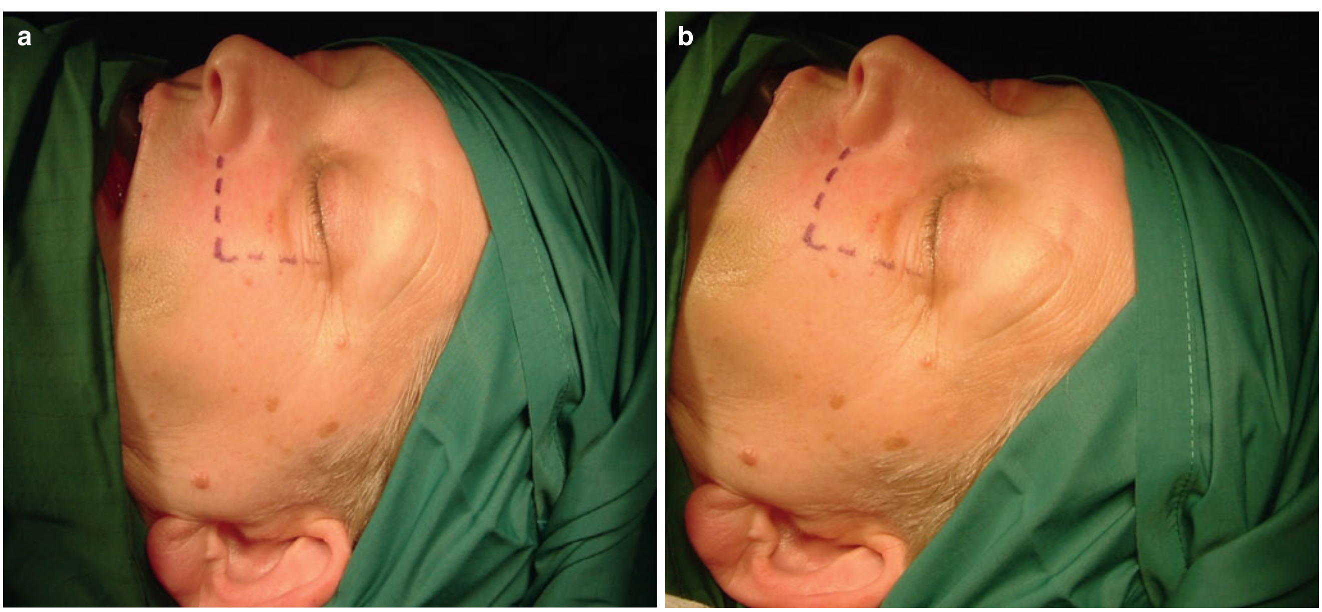

Fig. 8.56 The malar hook technique. The surface marking of the incision is seen here (**a**, **b**). The incision should lie around the maximum projection of the zygoma

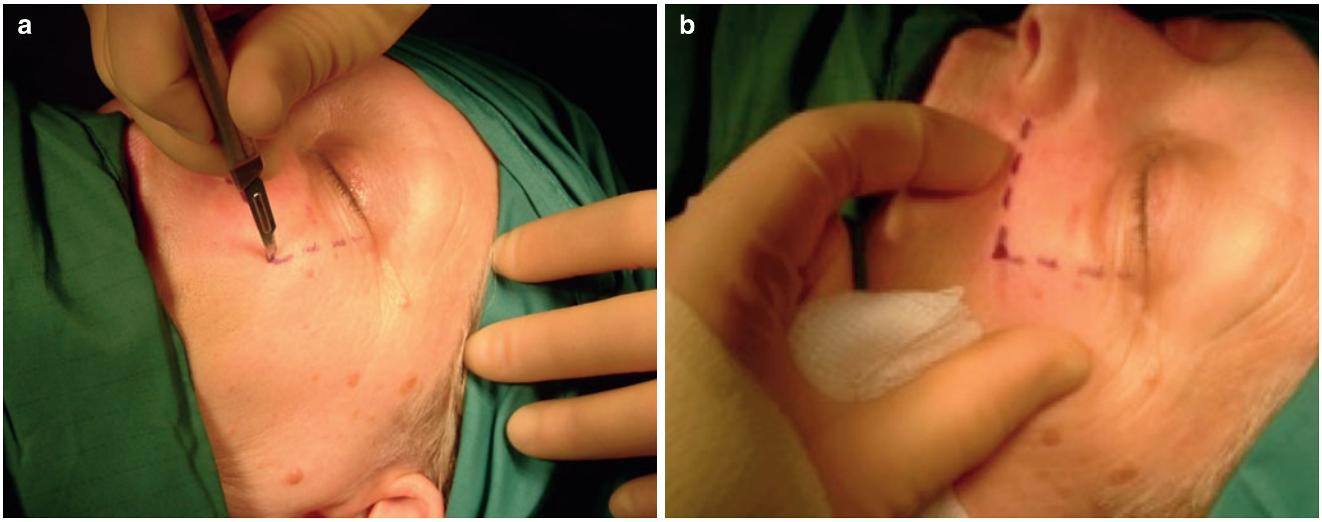

Fig. 8.57 A small stab incision is made using a scalpel blade (**a**). This only needs to be long enough to pass the hook (**b**)

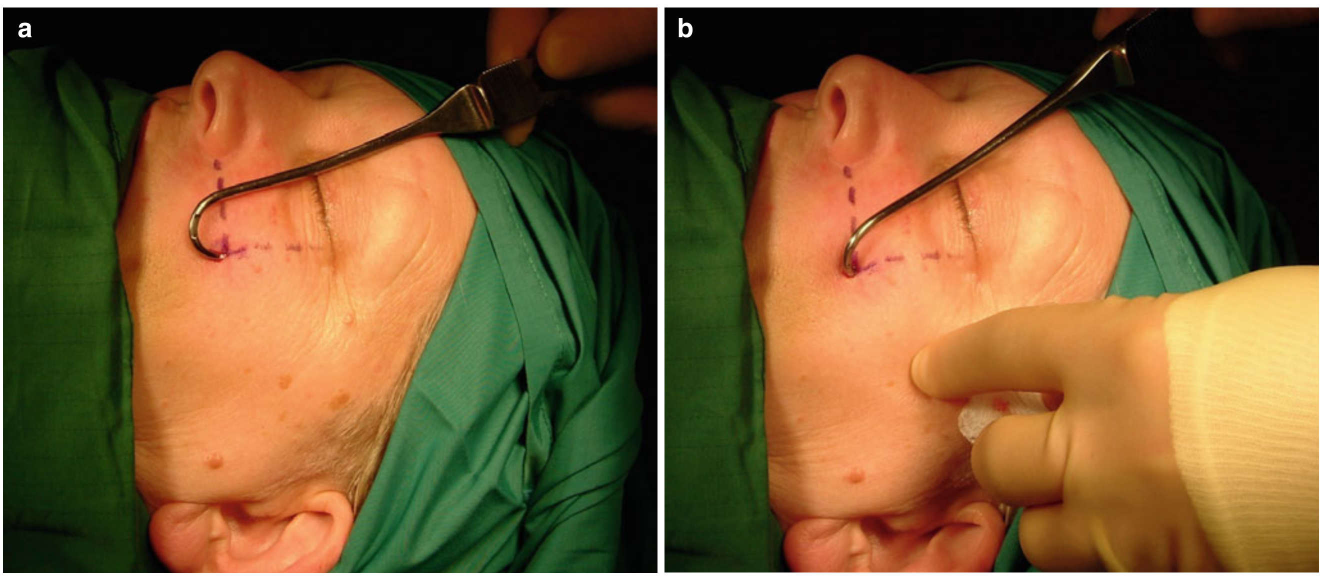

Fig. 8.58 The hook is passed through the skin until it is felt to engage the undersurface of the zygomatic prominence (**a**). Often a small "pop" is felt as the tip of the hook passes underneath the prominence (**b**)

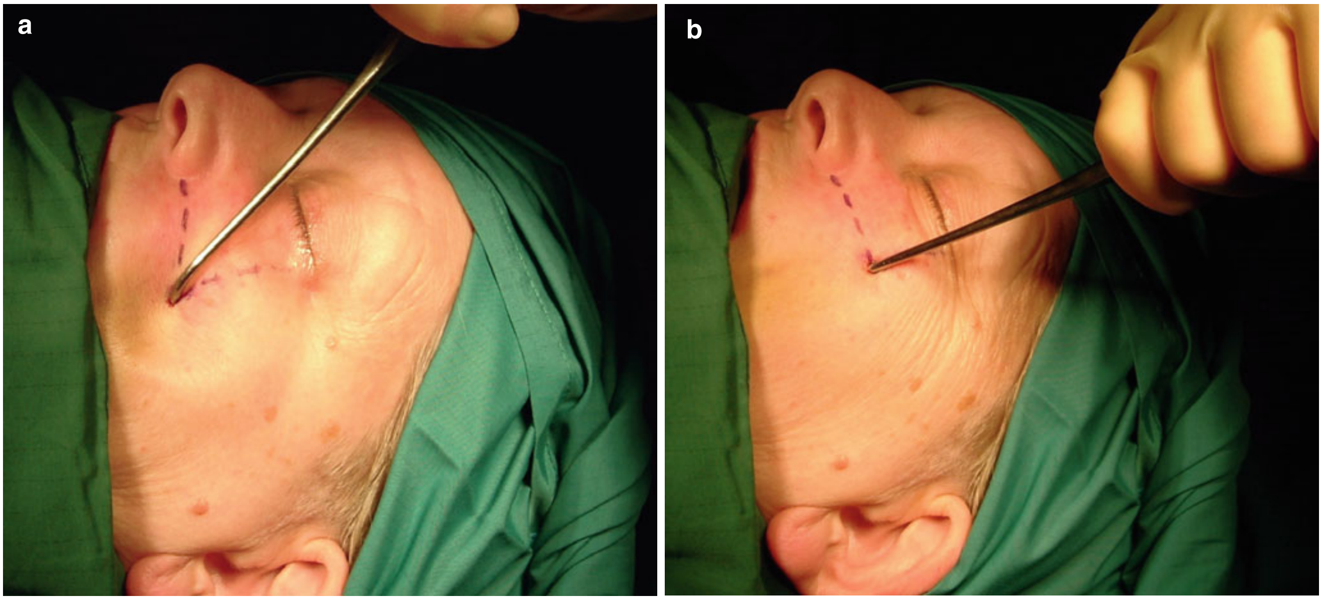

Fig. 8.59 The bone should always be fully engaged by the hook prior to elevation (**a**, **b**)

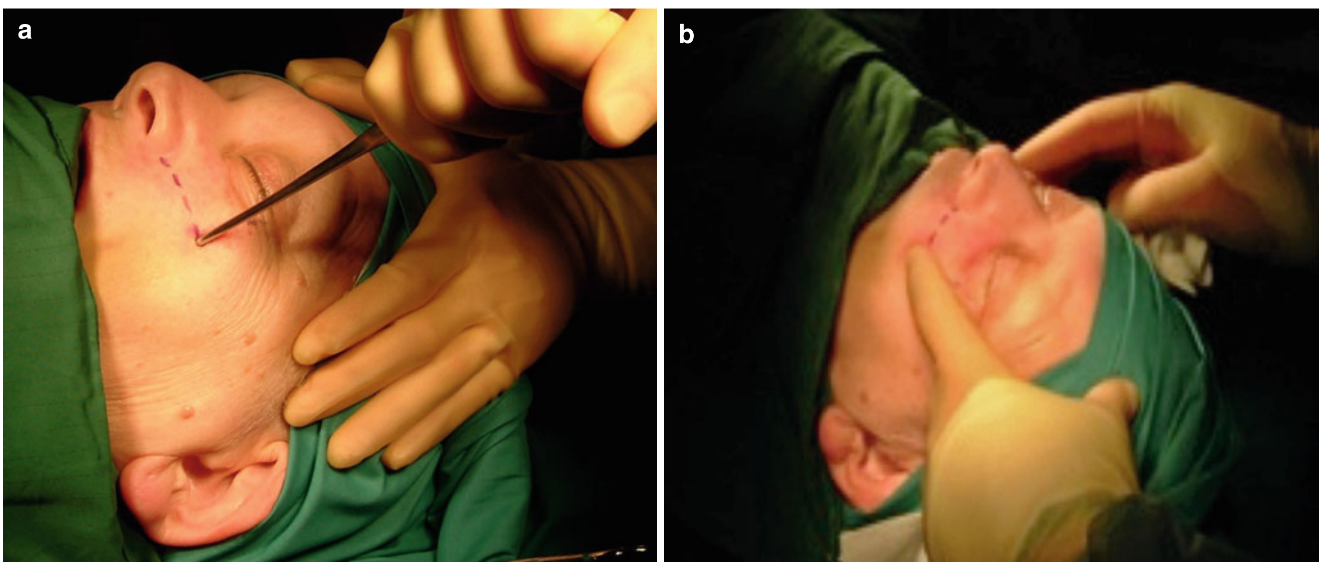

Fig. 8.60 The bone is then gently elevated, while supporting the head (**a**). Following removal of the hook, the patient is examined (**b**)

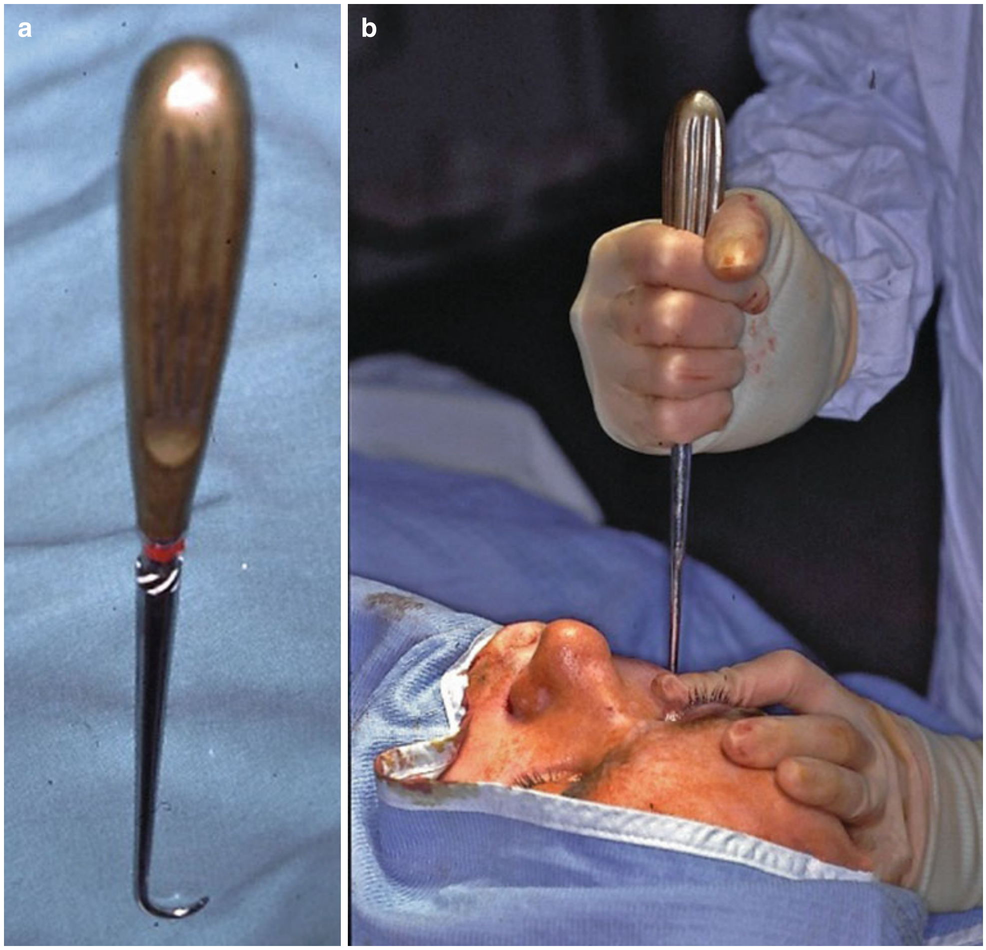

Fig. 8.61 Malar hook (**a**) and vertical elevation (**b**)

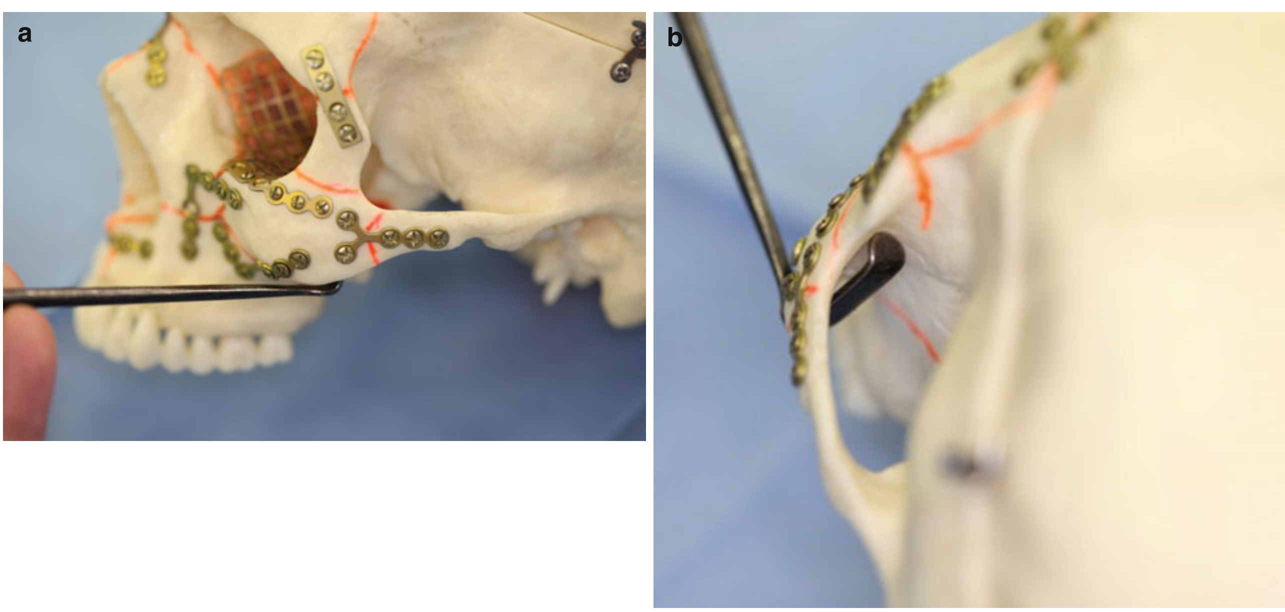

Fig. 8.62 Elevation is possible with other devises, such as a small retractor (Langenbeck) (**a** , **b**)

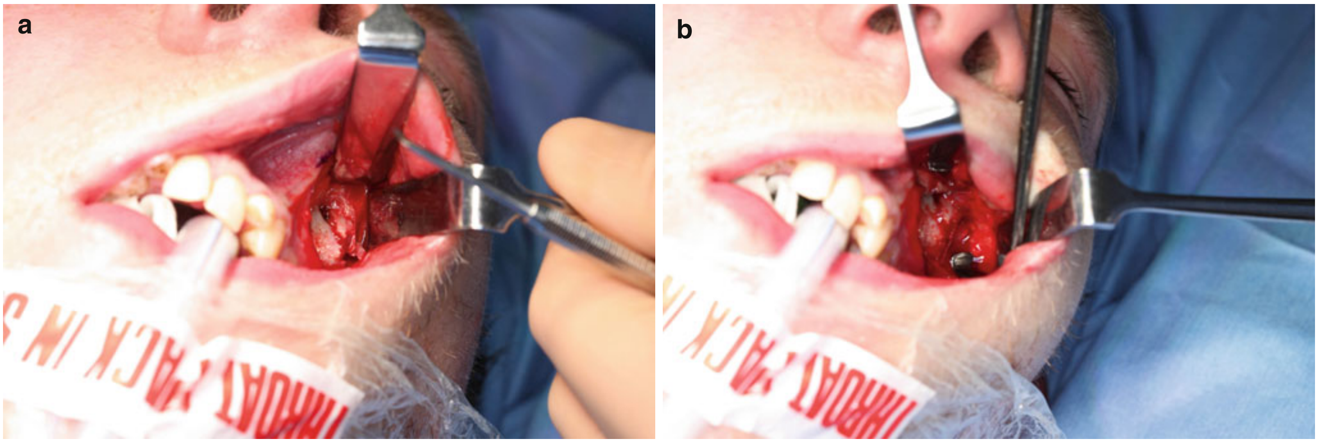

Fig. 8.63 The body and arch may be accessed via a transoral approach. This is known as the Keen approach (**a**, **b**)

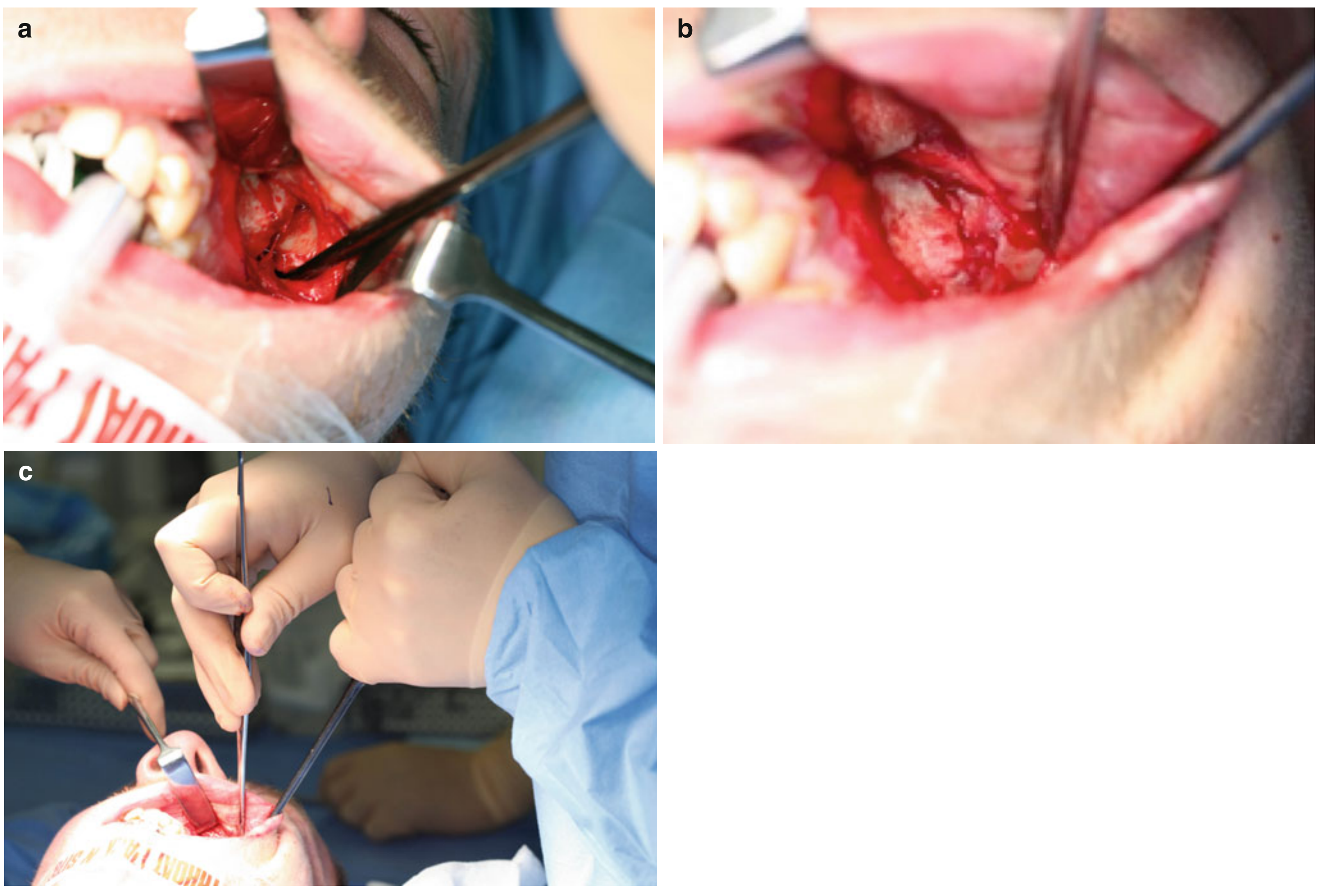

Fig. 8.64 The Keen approach is now a common technique for most simple fractures (**a**–**c**)

8.5 Isolated Arch Fractures

These are common injuries, often resulting from relatively low-energy mechanisms. It follows, therefore, that these injuries are commonly missed, and any blow to the side of the head must be examined carefully.

Patients will almost invariably complain of an inability to fully open the mouth. This will have implications for the anaesthetist, who should be informed. Sideways excursions of the mandible are also painful and limited. There is usually a visible depression of the arch, but this can be easily overlooked if there is swelling. Palpation in acute injuries may demonstrate a step deformity.

Assessment radiologically is either by plain film (submentovertex) as shown in Fig. 8.65, or by CT scan. Most injuries are V-shaped in nature with an intact periosteum. Provided that there is no separation at the fracture sites, these are usually stable on elevation. Instability of the arch should be anticipated if there are multiple fragments, management is delayed more than 2 weeks, or if there is separation or telescoping of the fracture sites indicating tears of the periosteum. Very occasionally a "floating" fragment may be seen. Arch fractures therefore need to be assessed carefully—some are intrinsically unstable and will require fixation. In most cases, however, the depressed arch can be simply elevated either via a Gillies approach or transorally (Keen approach). Access through the mouth is via an upper vestibular incision (described later). This allows the passage of a suitable elevator, which is positioned as shown in Fig. 8.66. The success of closed treatment again depends on interfragmentary locking.

Alternatively, in selected cases a strong suture can be passed under the depressed arch and used to elevate it. This is more of historical significance but is still worth knowing (see Fig. 8.67).

Case selection is very important. Suture elevation is a blind procedure undertaken without the correct instrumentation, but nevertheless is a useful "bail out" technique to know. This technique is unlikely to work if there is telescoping of the arch and is therefore best reserved for isolated depressed fragments of the arch and not fractures of the zygomatic complex. Its value lies in the fact that it is minimally invasive and relatively quick to perform, but successful reduction of the fractures may be difficult to ascertain in the grossly swollen face.

Fig. 8.65 Submentovertex view showing a depressed fracture of the left zygomatic arch

Most isolated arch fractures are stable once they have been lifted. This is due to the combination of interfragmentary locking and support from the thick temporalis fascia. However, occasionally an arch may fall back down and need support. Instability may be caused by poor alignment, overriding of the fragments, delay in surgery, or over-reduction causing secondary comminution of the fractures. Almost invariably this is predictable. Management of the unstable arch depends on a number of factors such as mouth opening and aesthetics (see Table 8.7). In some patients, the overlying soft tissues may camouflage a minor defect. Indirect fixation may be achieved using a suture and a Zimmer splint (see Figs. 8.68 and 8.69).

Fig. 8.66 Intraoral elevation of the zygoma. The elevator is positioned as shown (**a**–**c**)

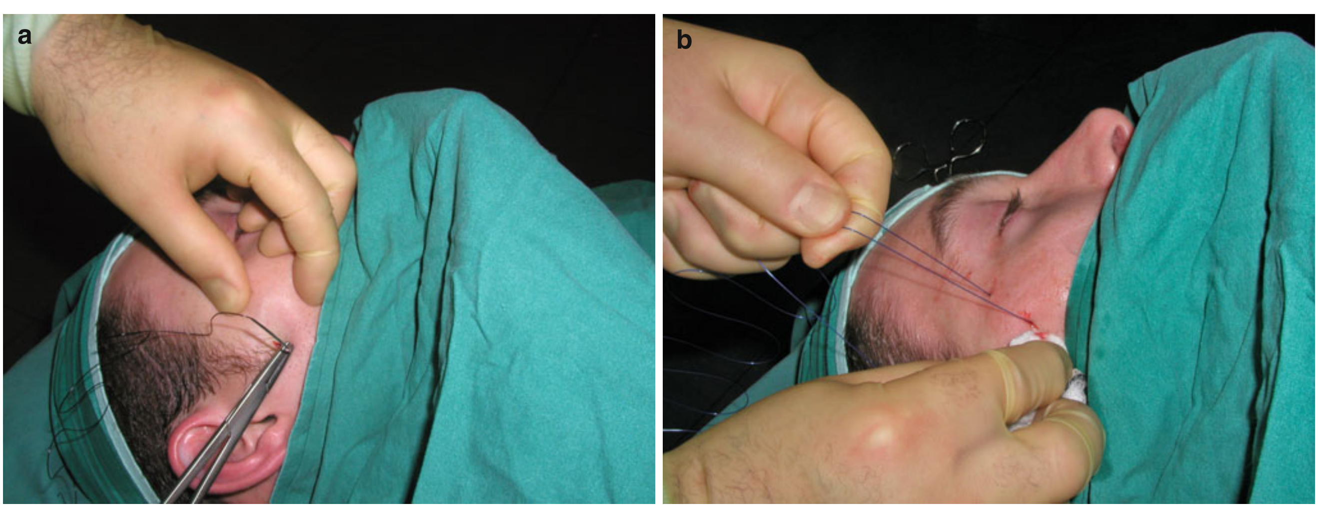

Fig. 8.67 Use of a traction suture to elevate a depressed arch (**a**, **b**). This is mainly a historical technique, but worth knowing as a "bail out" procedure

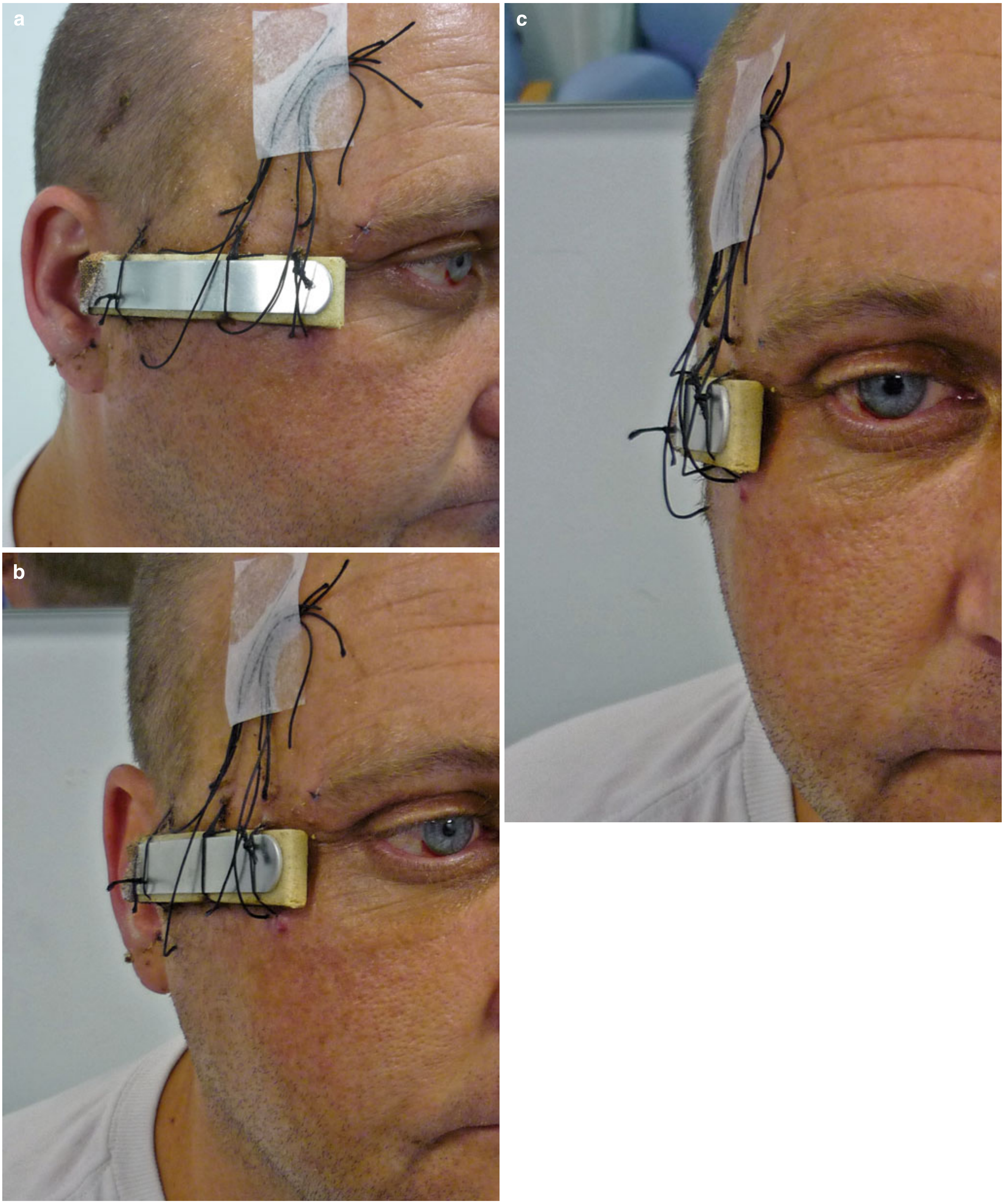

Fig. 8.68 To support unstable arches, a preformed aluminum splint with foam on the undersurface (Zimmer splint) is adapted to the shape of the reduced arch (**a**–**c**). Sutures are placed underneath the arch anteriorly and posteriorly and under the intervening fragments. These are tightened so the bone is reduced against the splint. The splint is maintained for around 2–3 weeks

Table 8.7 Management options in the unstable isolated zygomatic arch

Accept if minimal and deal with any problems secondarily
Suturing an external splint along the arch (suture is passed deep to arch and tied over the splint)
Balloon inflation deep to the arch (a Foley catheter will suffice)
ORIF (either through a preauricular or overlying incision)

Fig. 8.69 External support works best when there is little swelling. Otherwise the sutures loosen as the swelling resolves. Although a crude-looking technique, this is quick, simple, and avoids complex repairs. Minor defects may be acceptable or camouflaged secondarily by fat transfer or other onlay techniques

8.6 Open Reduction and Internal Fixation

Over the years, increasing confidence in surgical exposures of the face, together with the benefits of osteosynthesis, has resulted in a move towards open reduction and internal fixation (ORIF) of most facial fractures. This has a number of advantages. Firstly, exposure of the fractures allows for very accurate repositioning of the anatomy. Secondly, fixation with miniplates affords greater stability and confidence in the repair.

With regards to the ZMC, there has also been a general move by many towards ORIF of most fractures. This now involves fixation of at least one of the fracture sites, either with a "buttress" plate, or fixation across the FZ suture. This philosophy is based on concerns regarding masseteric and other displacing forces that may act on any unsupported reduction following closed elevation. A buttress plate can be placed transorally and an FZ plate through a small upper blepharoplasty incision. In both cases, scarring is virtually invisible.

However, this is a matter of personal preference, and closed techniques still have an important role to play in management. Exposure of the infraorbital rim should be avoided if at all possible. Scarring here may be more noticeable and can distort the lower eyelid. There is also the risk of injury to the infraorbital nerve. Fixation at this site is also the weakest of all the fracture sites. Nevertheless, infraorbital exposure may be necessary to access the orbit and/or repair multiple rim fragments.

The sites of repair must be considered in three dimensions, weighing up the pros and cons of accessing and repairing each site. A few key points are:

1. Usually the FZ suture is fractured in such a way that accurate reduction will result in satisfactory repositioning of the bone. This is because this part of the zygoma is very robust and rarely segmented. Repair of a disrupted FZ suture is especially important in reestablishing the vertical dimension of the cheek.
2. Repair or alignment of the infraorbital rim will correct and verify the transverse position of the bone, but carries a risk of eyelid distortion and palpable plates.
3. Repair of the zygomatic buttress intraorally, although very effective, can be technically difficult.
4. Arch repair will establish the anteroposterior positioning of the cheek prominence. However, it carries with it the disadvantage of an extended approach, which may be best avoided in advanced male pattern baldness, alopecia, or in patients prone to hypertrophic scarring.

Not all patients require fixation at all sites. Relatively few do. A stepwise approach is therefore needed in some cases and patients need to be consented appropriately. Sequencing is a matter of choice. Our general approach is shown in Table 8.8. In most fractures, either a closed approach or a single "buttress" plate will suffice (see Figs. 8.70, 8.71 and 8.72).

Table 8.8 Stepwise approach to open reduction and internal fixation of fractured zygoma (others exist)

1. Address the FZ suture first if it is significantly displaced. The purpose of fixation here is to reestablish the vertical height of the fracture, and the correct height of the lateral canthus and globe.
2. If necessary, reduce and repair the arch. This is only required occasionally in significantly telescoped arches, but it does necessitate a posterior approach (preauricular or cutaneous incision). The arch is key to cheek projection. Careful assessment is essential—even if it is not telescoped it may be bowed laterally and needs at least digital reduction.
3. Reduce and repair the lateral buttress. This is undertaken via an intraoral approach. In many cases, this may be the only procedure required, if the FZ suture and arch are not significantly displaced. This plate provides good mechanical stability.
4. Assess the infraorbital rim/orbital floor (force duction test) and expose if necessary.
5. Consider the need for bone grafting the buttress. This is rare and more likely in high-energy injuries.
6. Careful resuspension of the cheek prior to closure.

See also Fig. 8.71

Fig. 8.70 Most fractures of the ZMC can be adequately repaired with a single buttress or FZ plate or, as in this case, both

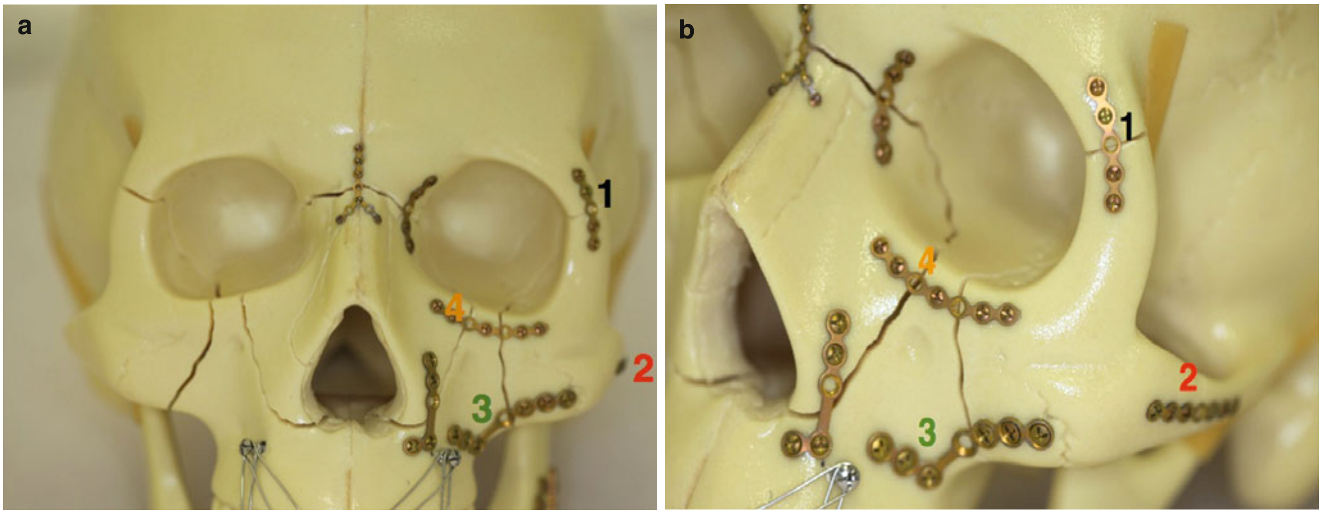

Fig. 8.71 Sequencing in repair (**a**, **b**). See Table 8.8 for details

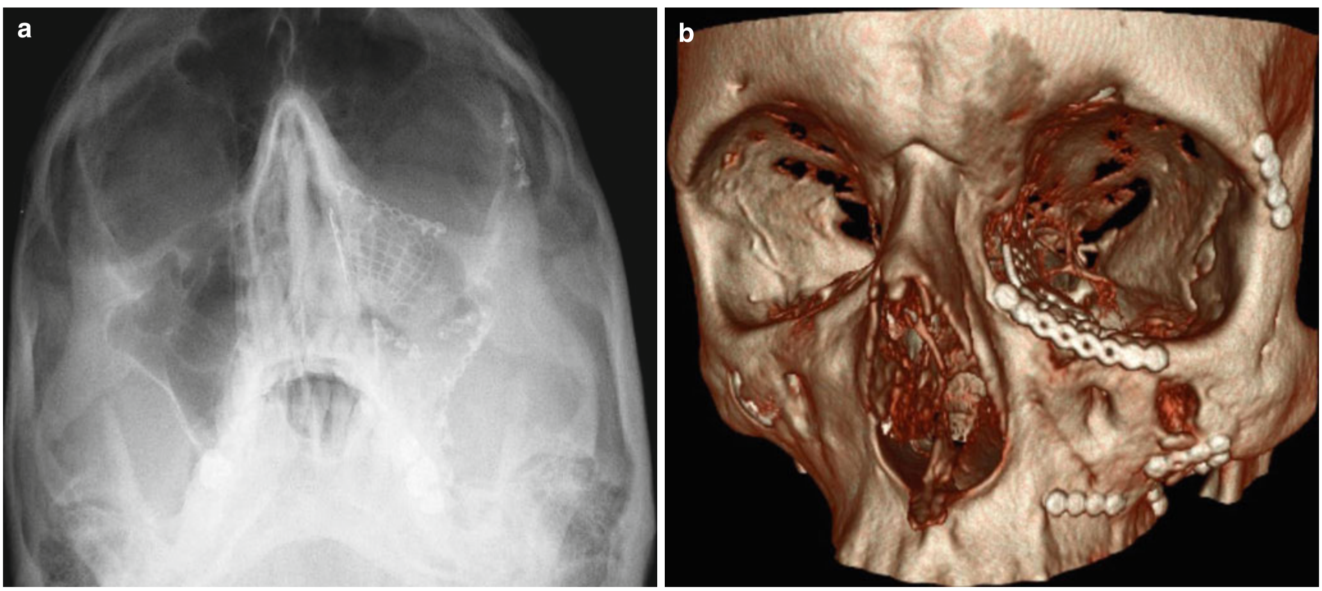

Fig. 8.72 Postoperative imaging following stepwise repair. The arch did not require fixation, as alignment and support was possible with the remaining plates (**a**, **b**)

8.6.1 Frontozygomatic (FZ) Access

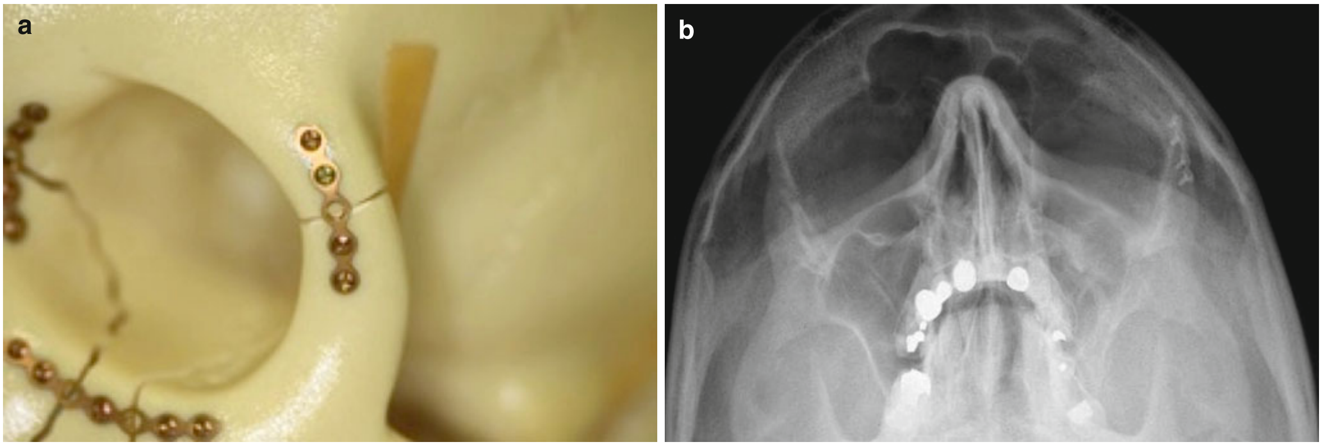

Fig. 8.73 The FZ suture is a key site in the assessment and repair of ZMC fractures (**a**, **b**)

The importance of the FZ suture was alluded to by Henderson, who considered it worthy of a separate class in his classification. Separation of the suture commonly occurs in fractures of the zygoma and other high-energy injuries to the upper face. Its precise repair is a key element in the restoration of orbital aesthetics. If the suture is seen to be separated on imaging, then it is highly likely that it should be exposed and plated. However, if the separation is very slight it can sometimes be compressed from below. Careful assessment of the intraoral buttress is then important.

If the lower fragment below the suture is displaced medially, then exposure is mandatory, particularly if it overlaps the upper one. When separation is significant, the zygoma (including the lateral canthus and globe) may drop vertically. Slanting of the palpebral fissure then occurs, giving an appearance that is sometimes called an "antimongoloid slant" If the FZ suture is disrupted as part of more complex midfacial injuries, incorrect reduction will build in errors in the overall repair, making accurate reconstruction impossible. The main aim of repair at this site therefore is to restore the correct vertical position of the lateral part of the midface including the eyelids and the globe.

Access to the FZ suture is possible through several routes, some of which, although easy, may be best avoided. An eyebrow incision (placing an incision within or just above the lateral third of the eyebrow) provides good access to the region. However, despite meticulous closure, scarring is usually visible in the eyebrow. The upper blepharoplasty incision provides excellent access. If sited correctly, it results in a very fine scar that is only visible when the eyelids are closed. In more significant injuries, this region may be approached using a coronal flap.

8.6.1.1 Upper Blepharoplasty Approach

Case 1

This approach involves making an incision within the skin of the lateral third of the upper eyelid extending, if necessary, beyond the lateral margin of the lid into the adjacent skin. Meticulous haemostasis is required to prevent post-operative bruising. Once the skin has been incised, dissection towards the fracture is undertaken, either with a scalpel or scissors. During this part of the dissection it is important to avoid dissecting into the eyelid itself, especially the levator apparatus. This can be avoided by simply pulling the wound gently upward and laterally, so that it sits over the bone and then dissecting towards the fracture. The skin in this region is usually highly mobile and it is quite surprising how much access can be gained through a relatively small incision. Retraction of the skin is best done using a small malleable retractor placed medially and a small retractor (such as the blunt end of a "catspaw") laterally. The malleable retractor also helps to protect the globe from any injury during dissection and repair. Once the periosteum is reached, it is incised along the curvature of the underlying bone and then elevated to expose fracture (see Fig. 8.74–8.80).

Fig. 8.74 Fracture and incision is marked (**a**) and local anaesthetic placed (**b**)

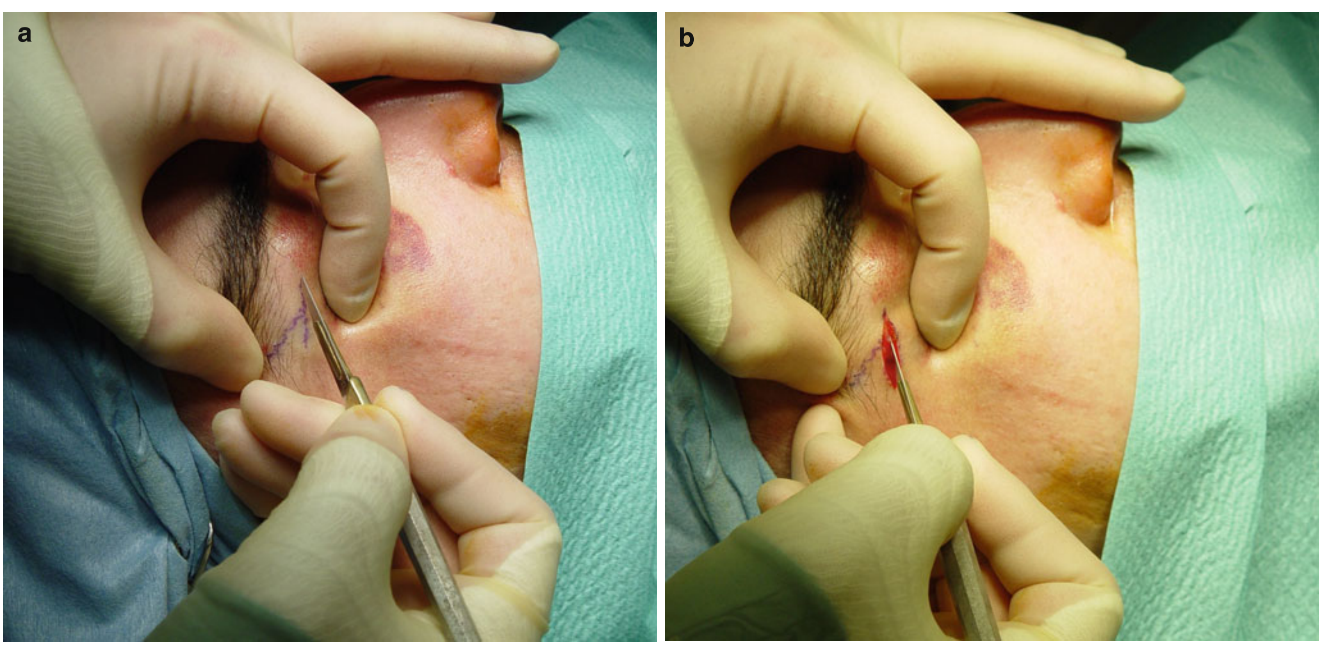

Fig. 8.75 Skin incision (**a**, **b**)

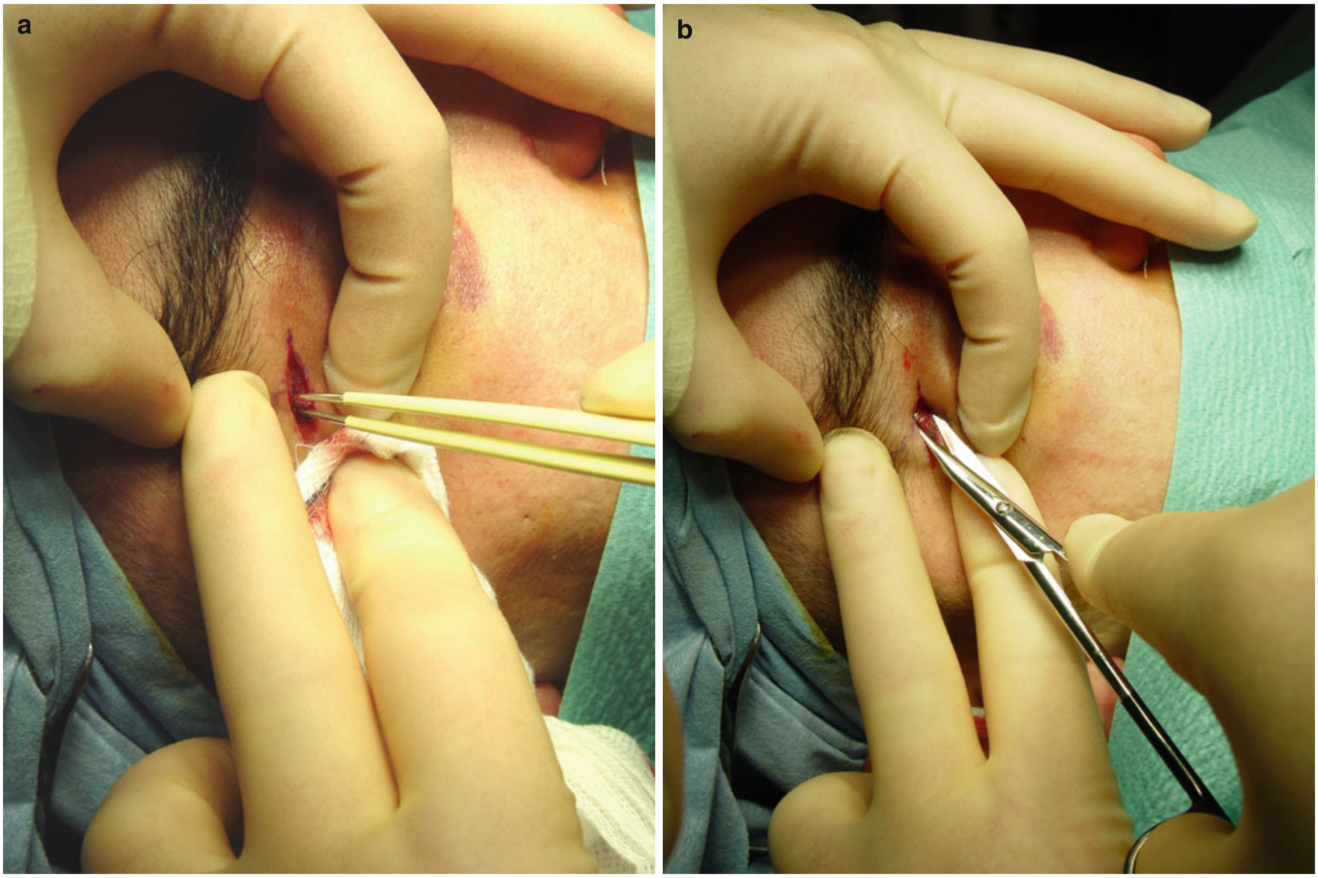

Fig. 8.76 Haemostasis (**a**) and blunt dissection (**b**) to periosteum

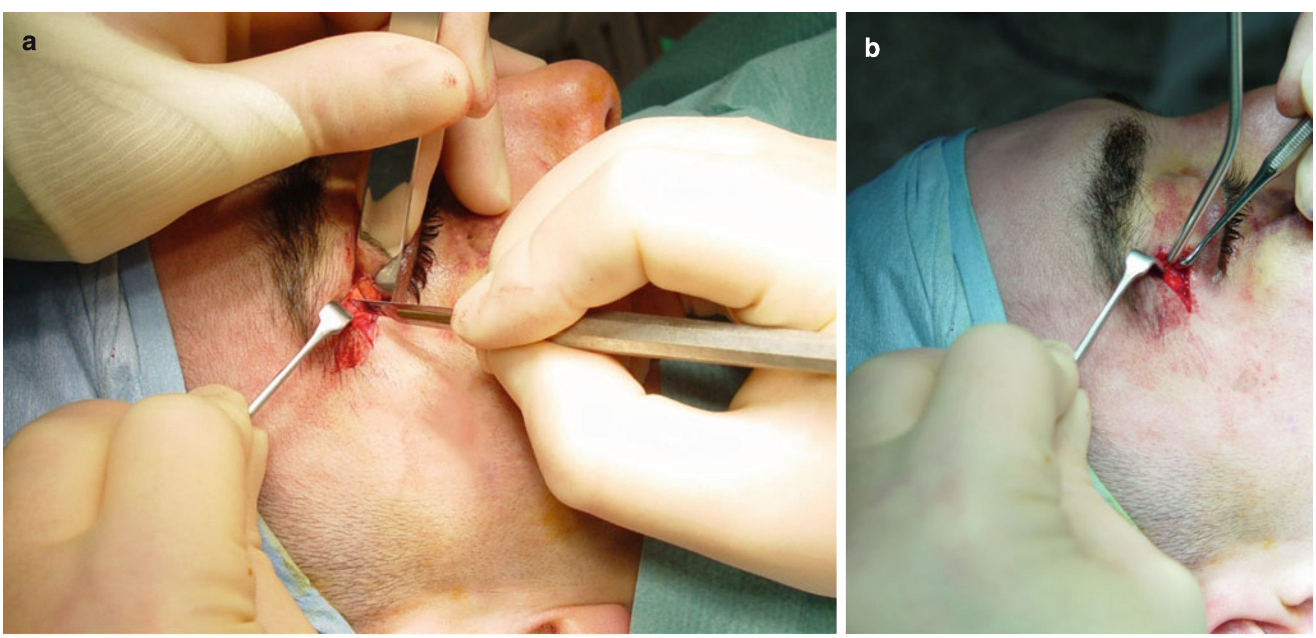

Fig. 8.77 The periosteum is incised (**a**) and elevated (**b**)

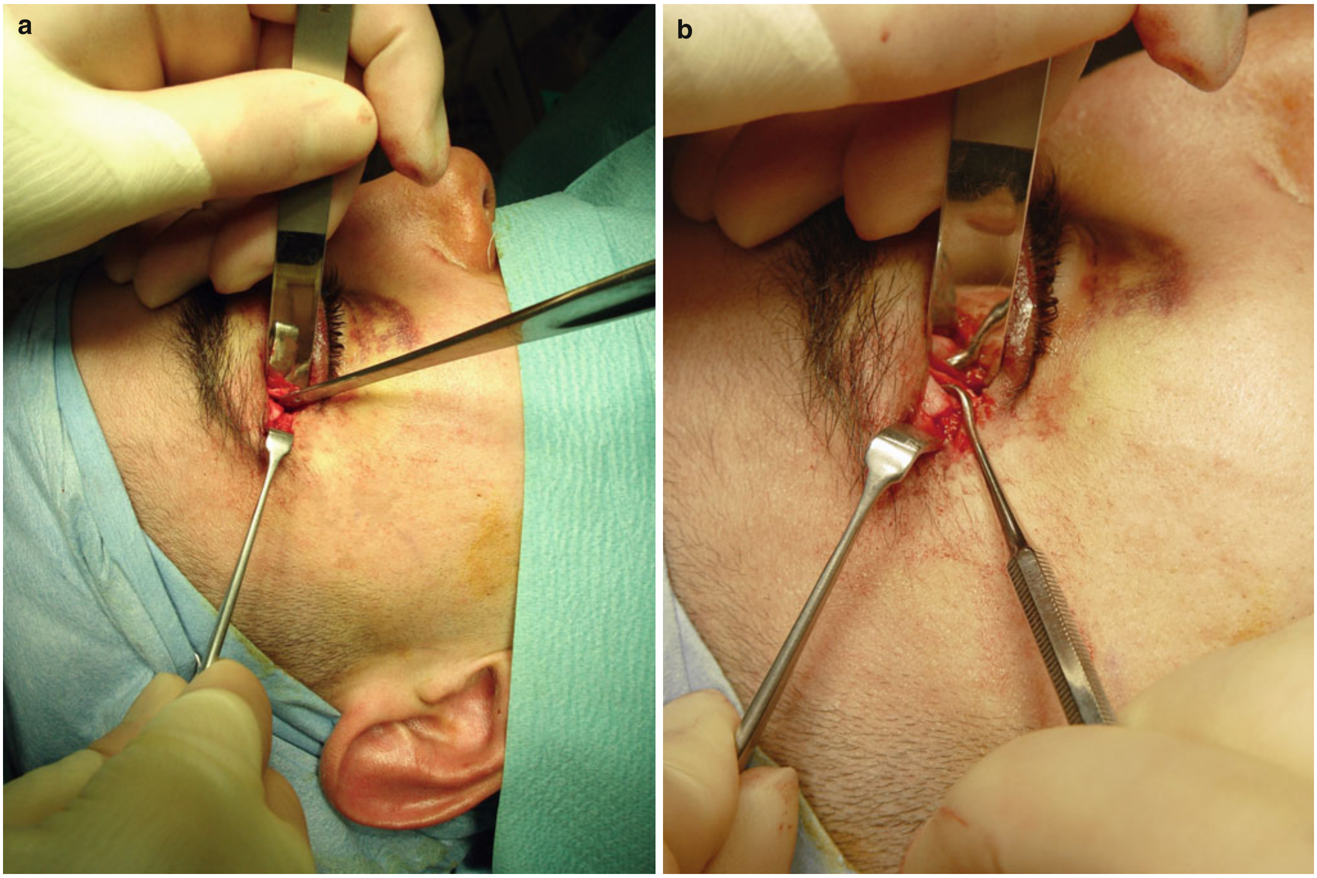

Fig. 8.78 The FZ suture is exposed enough to allow plating (**a**, **b**)

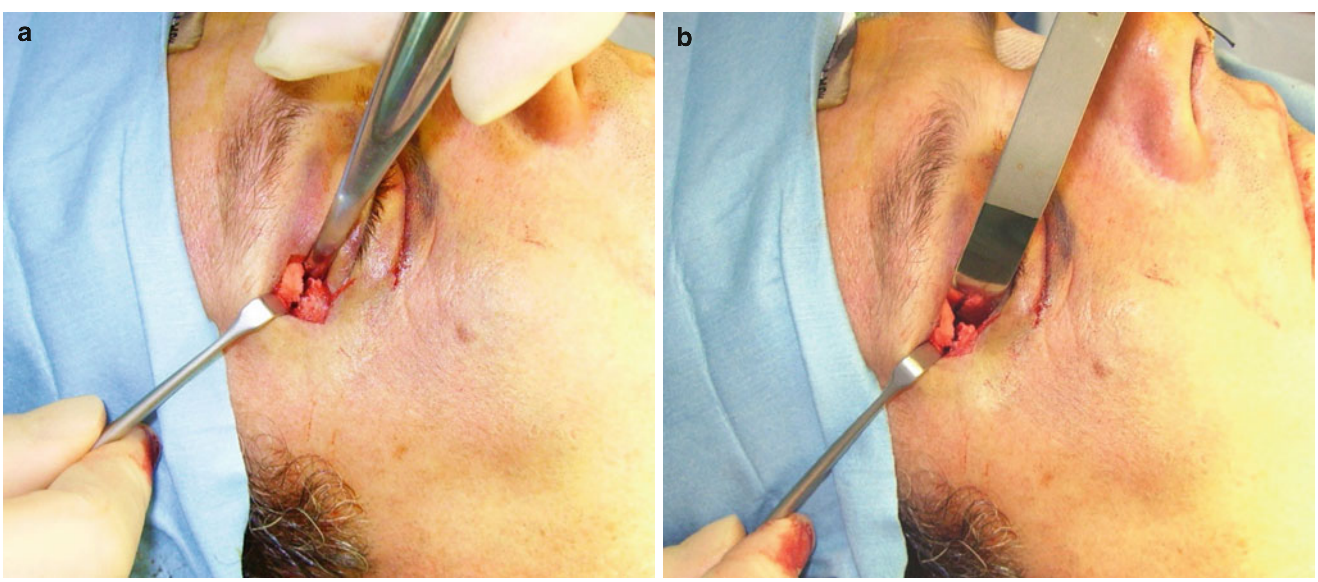

Fig. 8.79 Exposure (**a**) and globe protection (**b**)

Fig. 8.80 This access also allows inspection of the lateral wall, another key site in management

This incision also provides excellent access to the lateral orbital wall, an important site to inspect following fracture repair. Correct alignment of the lateral orbital wall is a good indication that the zygoma has been restored to its correct position. In some cases, the lateral orbital wall itself can be secured with a plate (see Fig. 8.81).

Closure is done in layers.

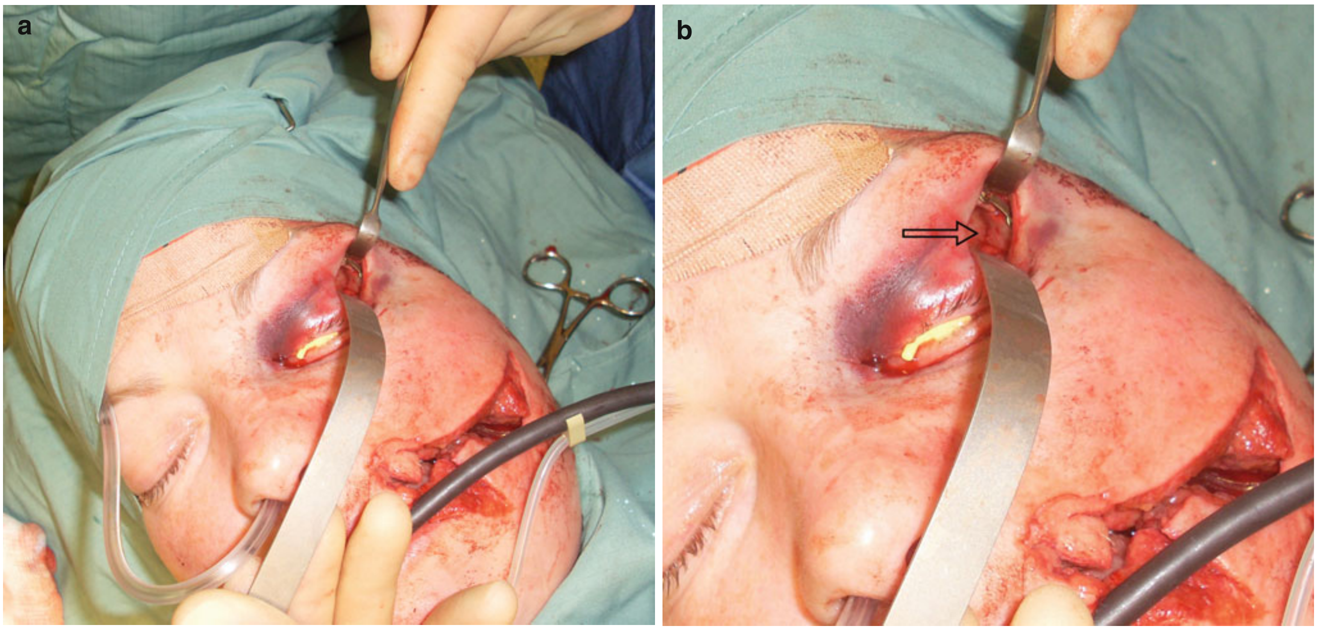

Fig. 8.81 Visualisation of the lateral wall following elevation (**a**). There is good reduction at the FZ but still a small amount of displacement lower down (**b**). Further adjustment was required prior to fixation

Case 2

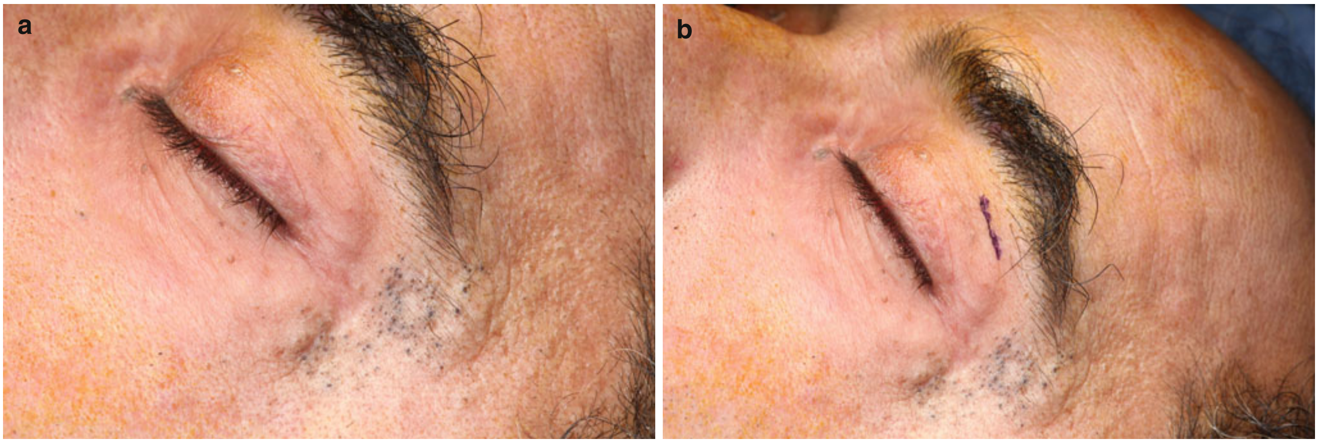

Fig. 8.82 Incision marked in a suitable skin crease (**a**, **b**)

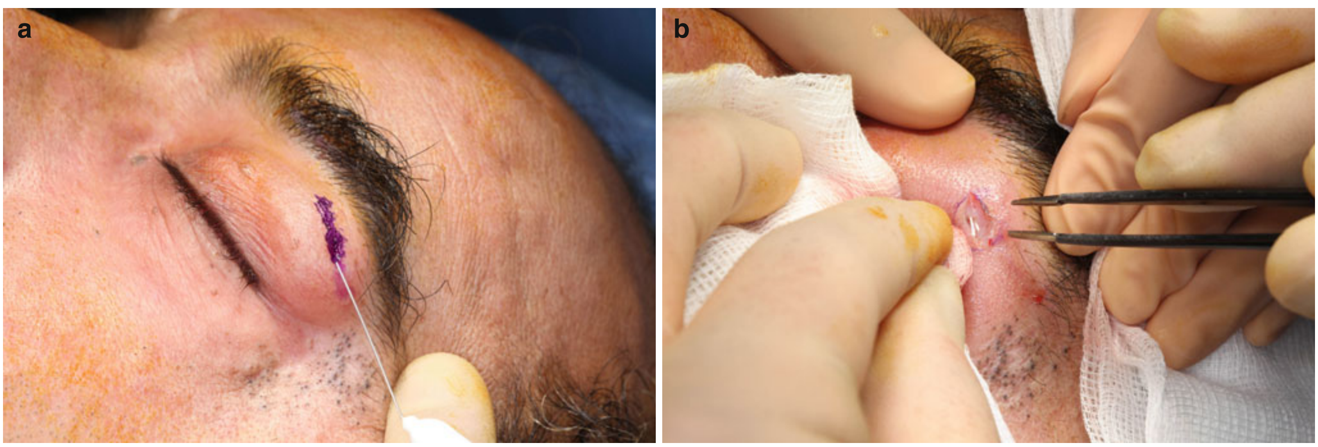

Fig. 8.83 Following local anaesthetic (**a**), dissection commences (**b**) as described in case 1

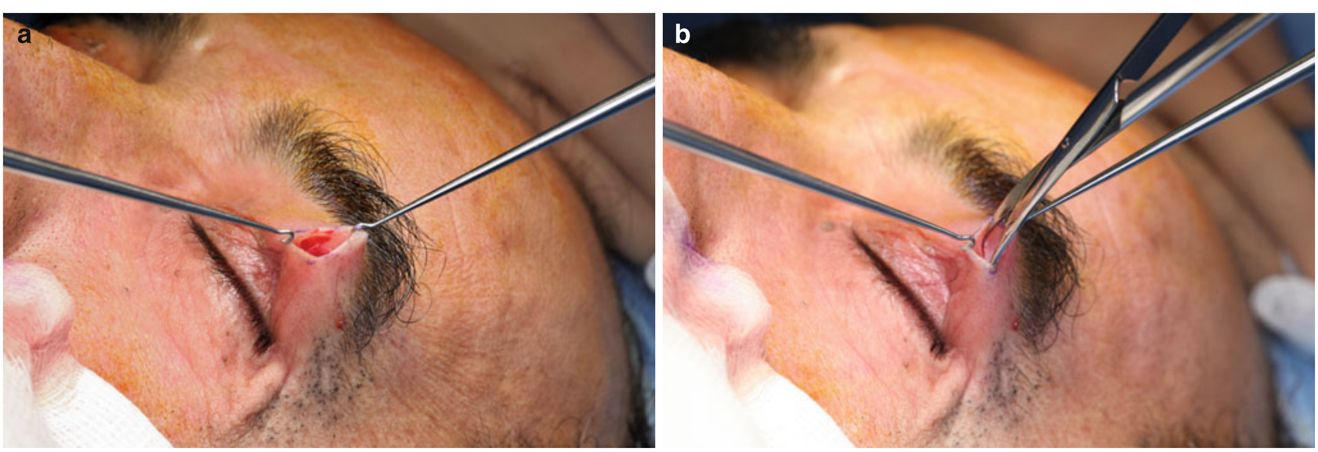

Fig. 8.84 Haemostasis (**a**) and blunt dissection to periosteum (**b**)

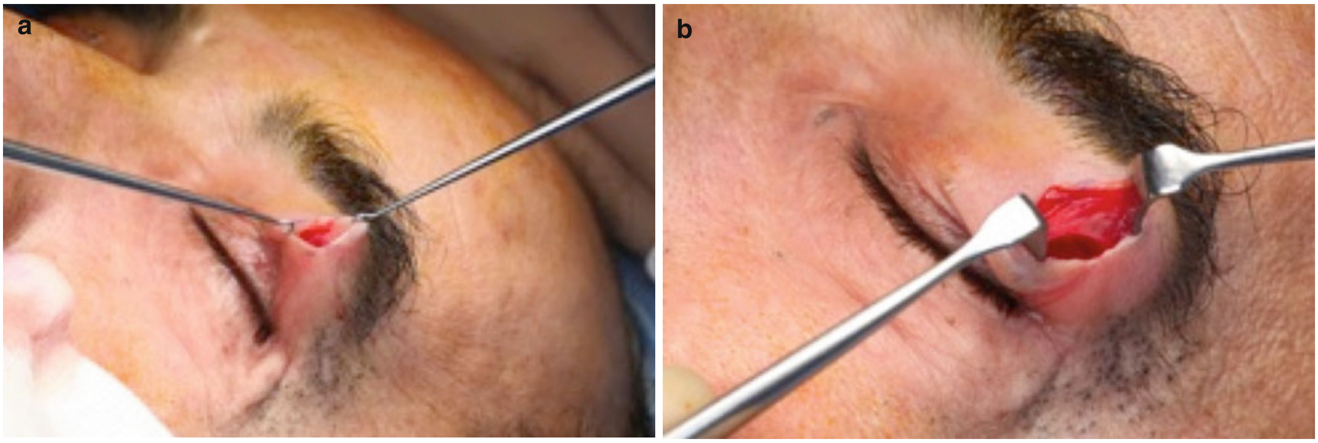

Fig. 8.85 The mobile skin allows surprisingly extensive access through a small incision (**a**, **b**)

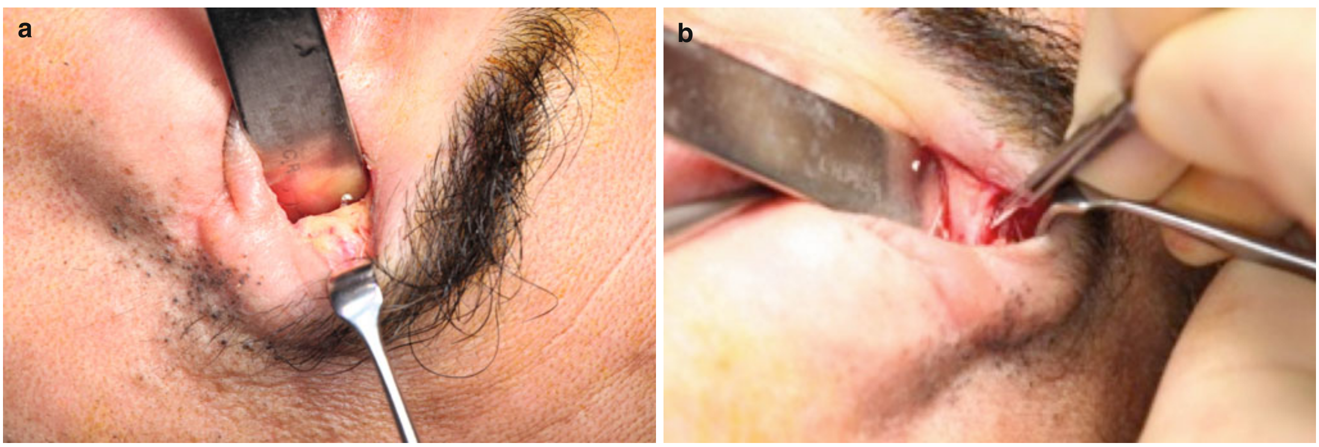

Fig. 8.86 The periosteum is incised (**a**) and elevated (**b**)

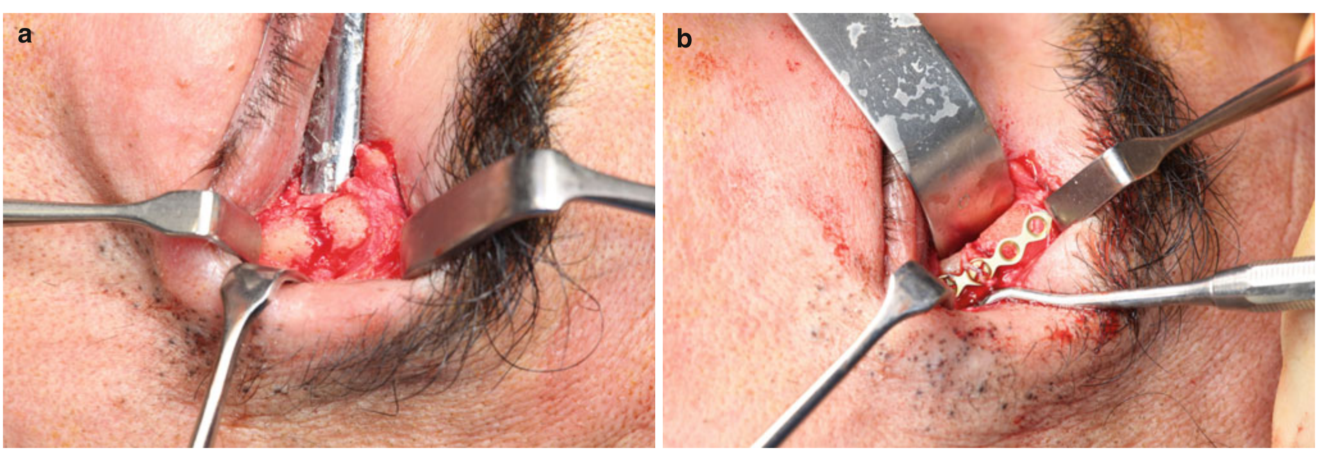

Fig. 8.87 The fracture is reduced (**a**) and a plate secured to the lower fragment (**b**)

Fig. 8.88 The plate is the pulled superiorly (**a**) while the zygoma is manipulated (**b**). This compresses the fracture and helps with anatomical reduction. Vertical dimension should be restored

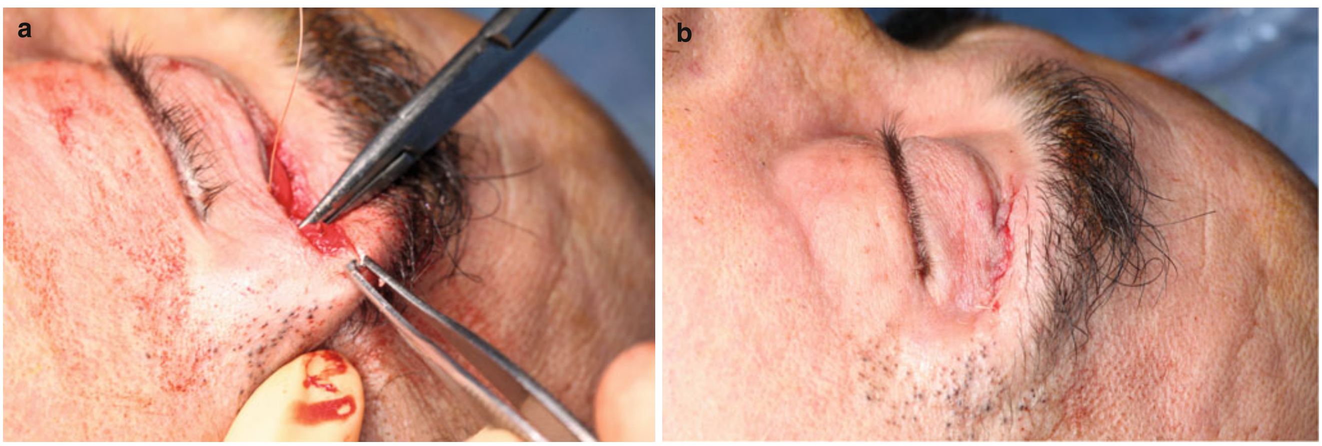

Fig. 8.89 The wound is closed in layers (**a**, **b**)

8.6.2 Buttress Plate (Intraoral Access)

Fig. 8.90 The zygomatic buttress provides excellent three-dimensional support when accurately repaired (**a**–**c**)

Repair of the intraoral buttress is considered by many authorities to be an important element in the repair of zygomatic fractures. In many cases, the intraoral incision required for osteosynthesis can also provide access for reduction, thereby avoiding the need for a temporal incision and Gillies lift. The incision being intraoral is of course extremely cosmetic, and well tolerated.

Access can be achieved relatively easily through a small incision placed in the vestibular sulcus, just above the upper limit of the attached gingiva. The precise siting of this incision is not crucial, although avoidance of the attached gingiva itself should reduce the likelihood of gingival recession postoperatively. It is therefore important to leave enough of a cuff to allow tension-free closure (a minimum of 5 mm above the attached gingiva). If the incision is extended too far laterally, the buccal fat pad may be encountered and can herniate through the wound.

Cutting diathermy is particularly useful with intraoral incisions as this helps to minimise bleeding. Following the mucosal incision, a second incision is placed through the deeper tissues, down to bone. The periosteum is then incised with a scalpel blade and the periosteum carefully elevated from the buttress. Some surgeons may incise this as one layer. In cases where the buttress is comminuted, the periosteum must be raised carefully, otherwise loose fragments may be displaced into the antrum, making retrieval and precise reduction difficult. Enough periosteum is raised to expose the full extent of the fracture and identify the uppermost fragment of bone at the zygomatic prominence. The bone fragments are then gently manipulated, anatomically

Case 1

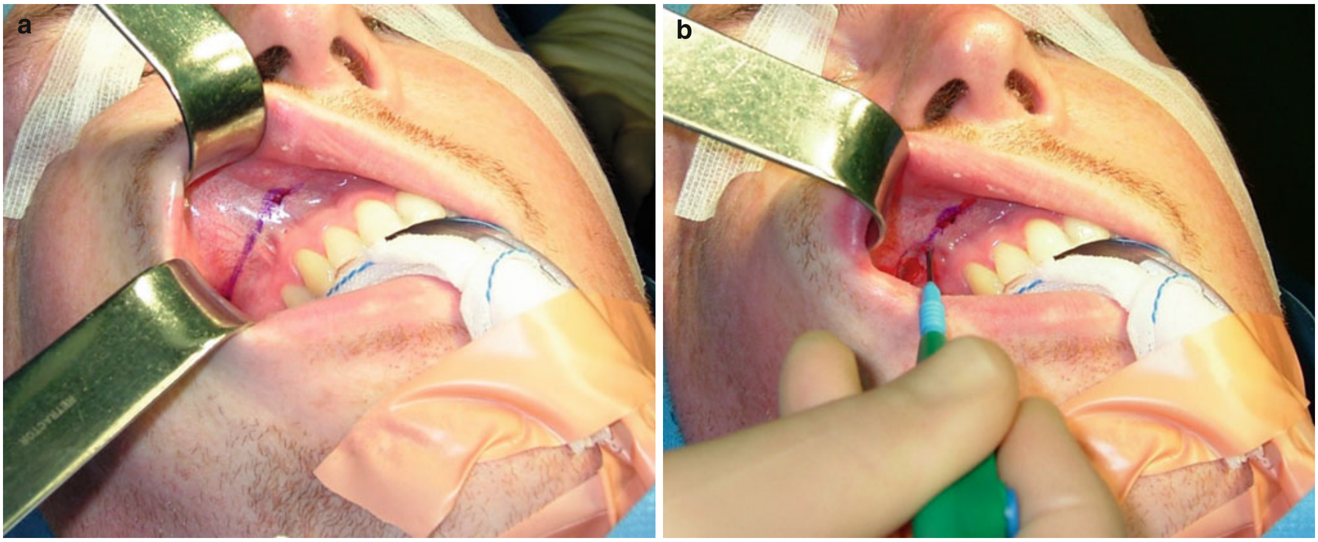

Fig. 8.91 The incision is marked (**a**). Cutting diathermy is very useful for this (**b**). It minimises bleeding

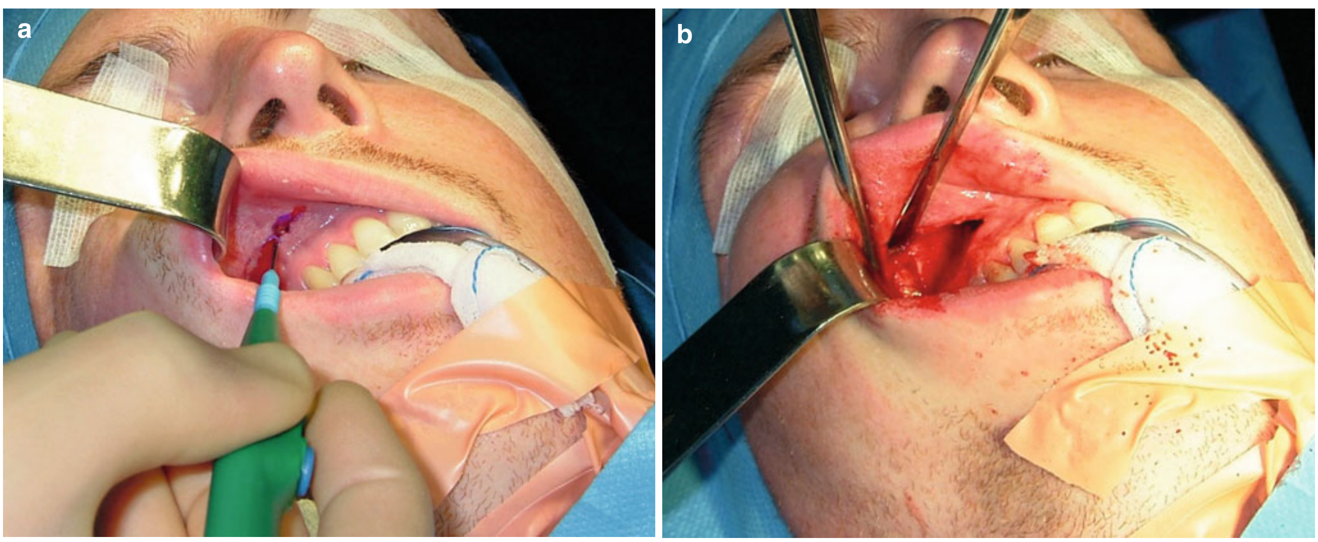

Fig. 8.92 The incision is deepened and the periosteum incised. Careful elevation is required as the fragments can easily displace

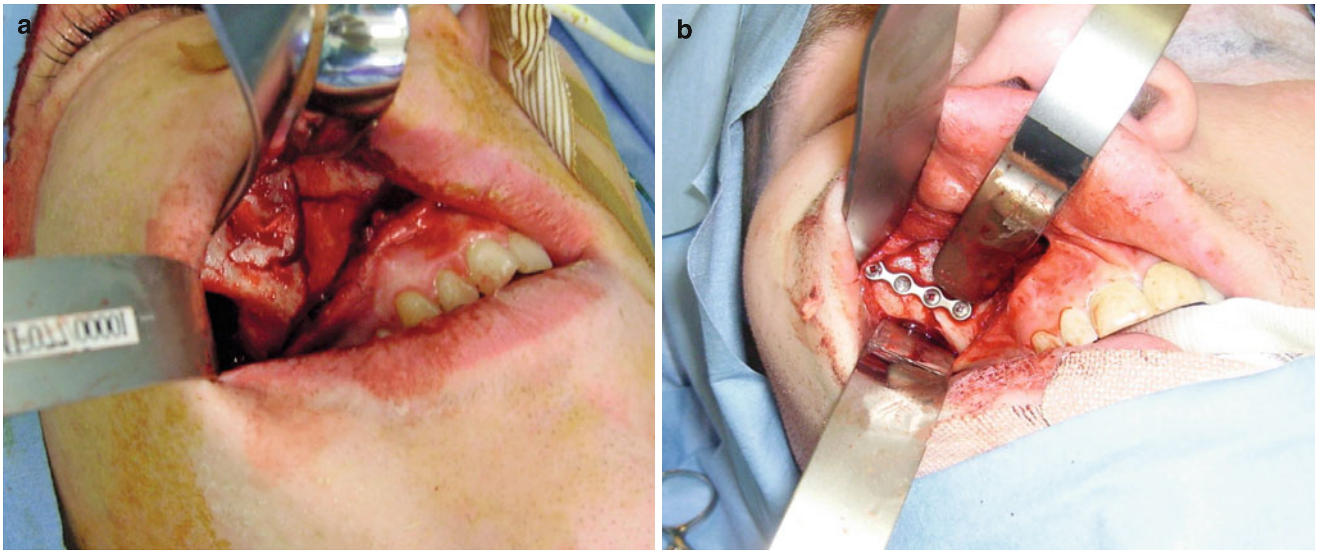

Fig. 8.93 The fracture is reduced and plated (**a**, **b**). The plate is placed as laterally as possible. Bone is thickest here

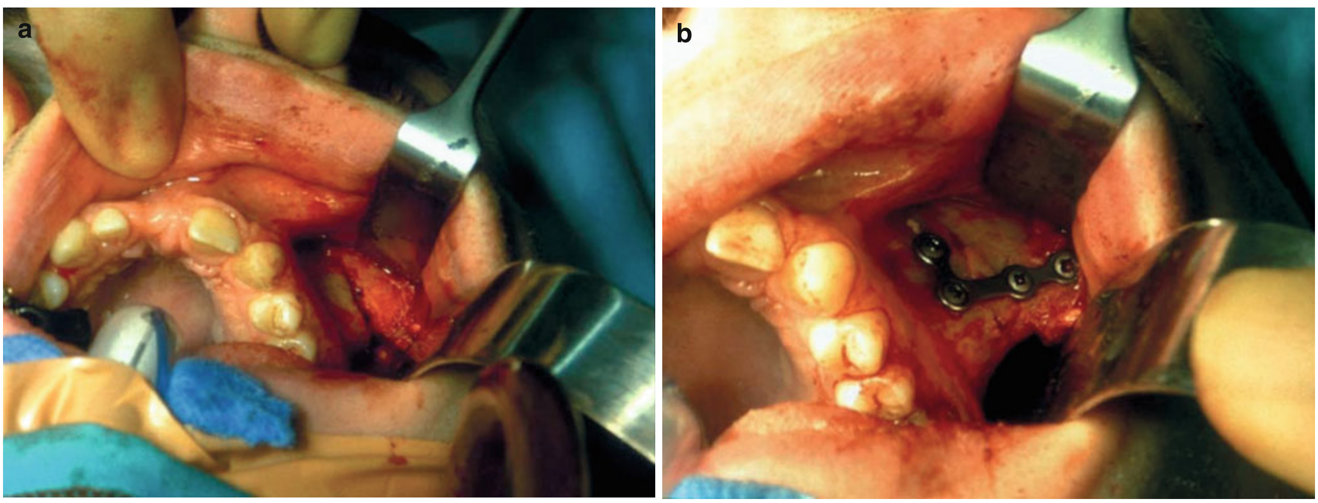

Fig. 8.94 In this example, a reverse-shaped “L” plate has been used (**a**, **b**)

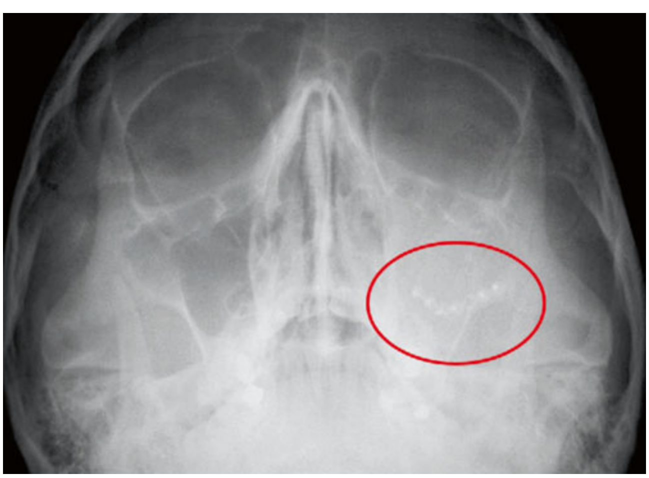

Fig. 8.95 Postoperative film. *Red oval* indicate the plate position

Case 2

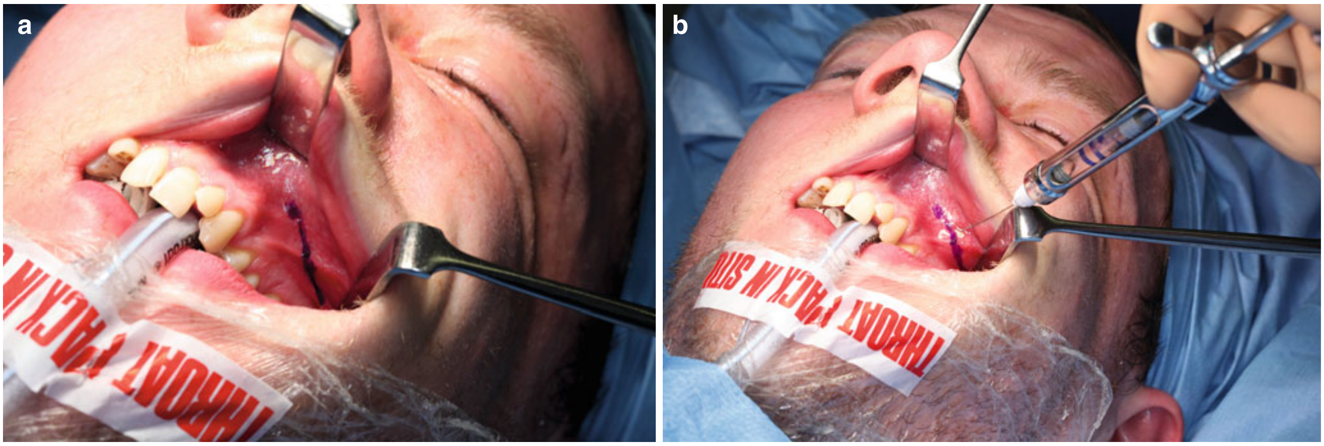

Fig. 8.96 Incision marked (**a**) and local anaesthetic placed (**b**)

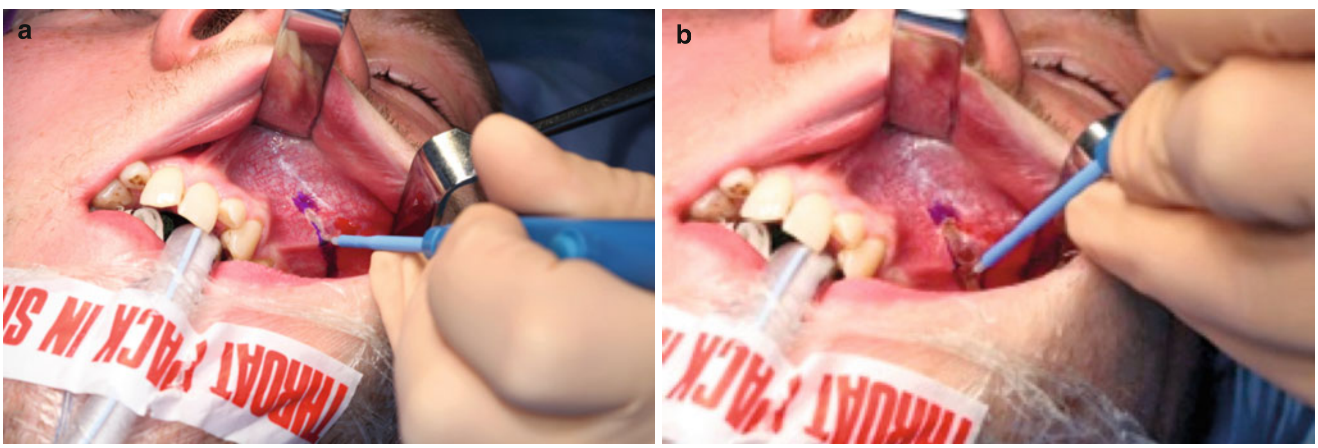

Fig. 8.97 Cutting diathermy can often produce a near bloodless field (**a**, **b**)

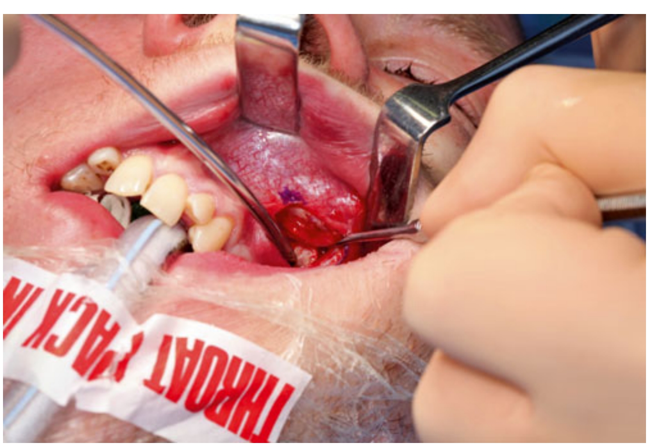

Fig. 8.98 The periosteum is carefully elevated

reduced, and fixed. Not all fragments need to be secured if the site is comminuted. However, it is important to try to repair the thickest part of the buttress laterally. It is this bone that provides a sound foundation for cheek support.

Smaller and thinner anterior fragments of bone can be removed, or secured with glue if preferred. These are not as crucial as the more thicker and lateral aspects of the buttress, but if they all fit together accurately it does provide a degree of reassurance that the fracture must be reasonably well reduced (remember bone is "plastic") (see Fig. 8.99).

Following fixation, closure of the wound can be undertaken with a suitable resorbable suture.

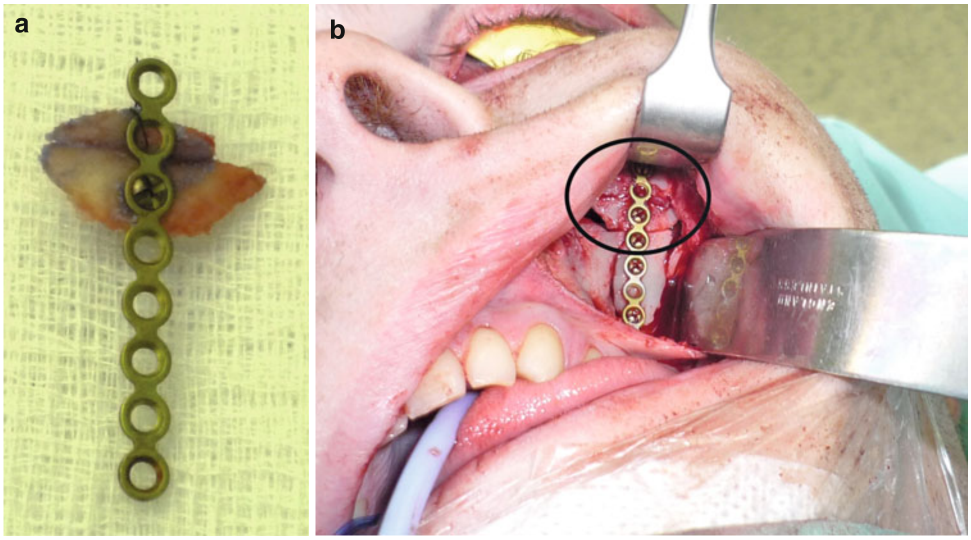

Fig. 8.99 Small fragments can be difficult to secure with a screw. They often split. Alternatively, they can be secured to the plate by a suture and glue. This helps verify an accurate reduction (**a**, **b**)

8.6.3 Infraorbital (Inferior Orbital) Access

This is discussed in detail in the chapter on orbital injuries. Although not a preferred routine incision (due to possible eyelid distortion), this approach may nevertheless be required if exploration or repair of the orbital floor is required. This approach also provides good visualisation of the lateral orbital wall (a key site in the assessment of accurate reduction). In some cases it may even be possible to plate the lateral wall through this incision) (see Figs. 8.100 and 8.101).

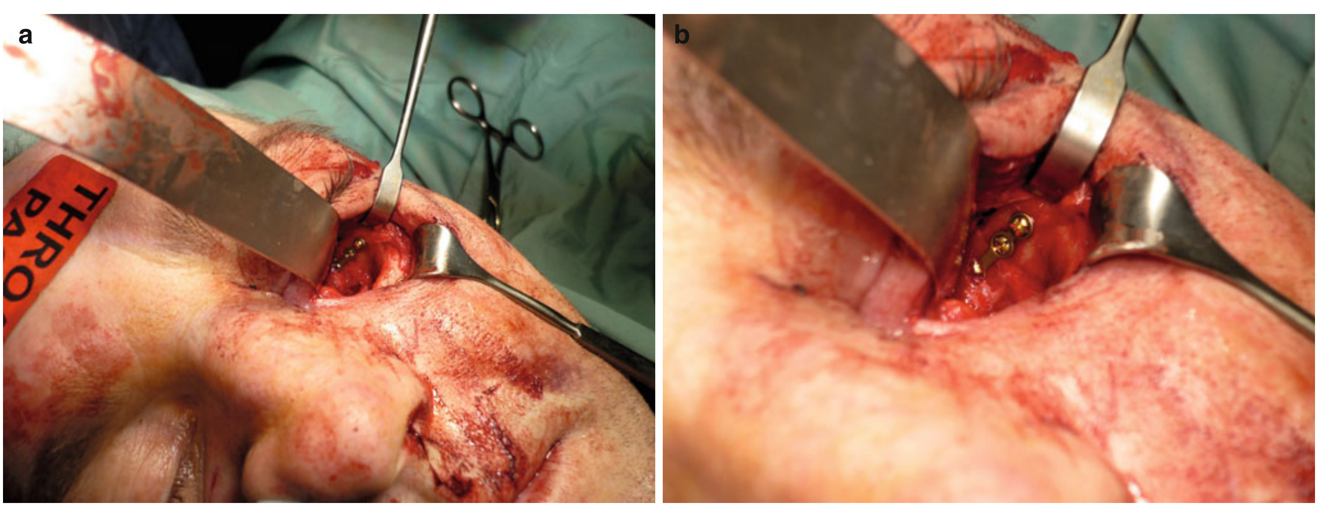

Fig. 8.100 Reduction of the lateral wall is a good indicator of overall reduction of the ZMC (**a**). In some instances, it can be plated to maintain satisfactory position (**b**)

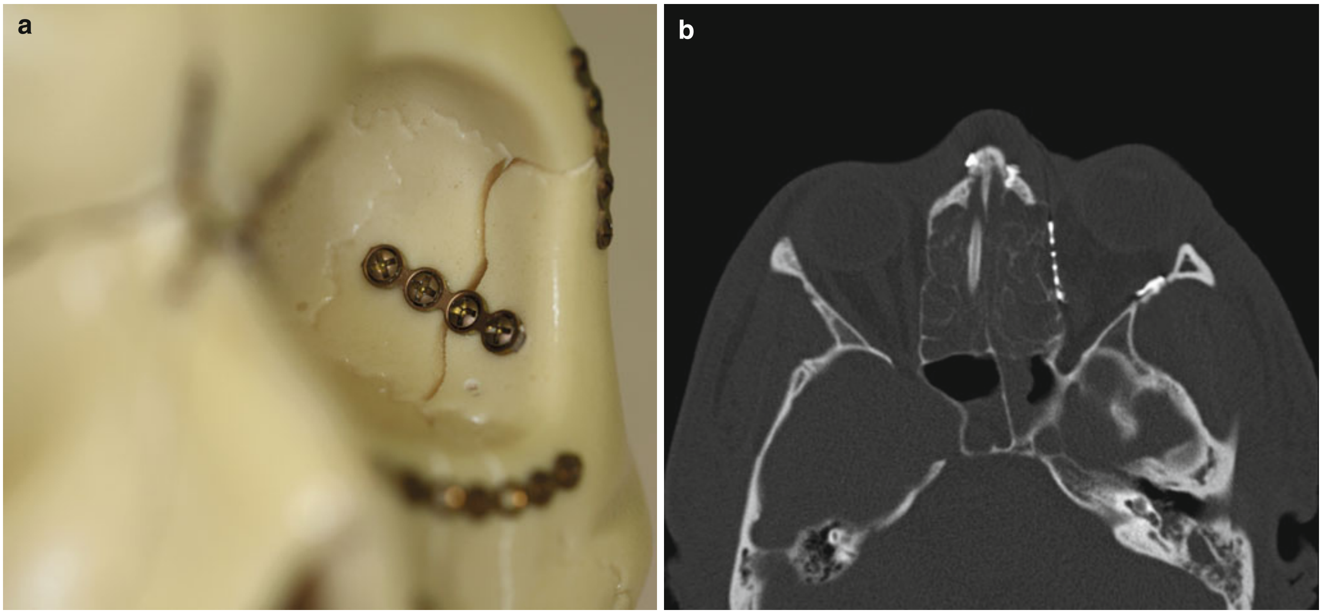

Fig. 8.101 Plate position on model (**a**) and on CT (**b**). The lateral wall is satisfactorily aligned

8.7 Zygomatic Arch Repair

The zygomatic arch is a key structure in the assessment and management of both fractures of the zygomatic complex and those of the midface. In essence this forms a horizontal strut of bone that projects the cheek in a forward direction (analogous to the importance of the nasal septum in producing nasal projection). It has a gentle curve to its shape (see Fig. 8.102).

A key component in treatment planning is therefore to assess how much the arch has been disrupted. In situations where the arch is bowed or buckled (but the ends of the fractures are in contact), it is likely that the enveloping periosteum is mostly intact. In such cases, fixation of the arch itself is often not required, so long as adequate fixation is placed elsewhere (notably the FZ suture and intraoral buttress). This is a general guide and not an absolute rule (see Figs. 8.103 and 8.104).

The more deformed or comminuted the arch appears to be, the more likely it is that fixation will be required. "Telescoping" of the arch is a sign of increased instability and potential for loss of cheek projection postoperatively. In such cases, the periosteum will be torn and therefore precise and stable realignment of the bone is less likely without fixation. In such circumstances repair of the arch may be required (see Fig. 8.105 and 8.106).

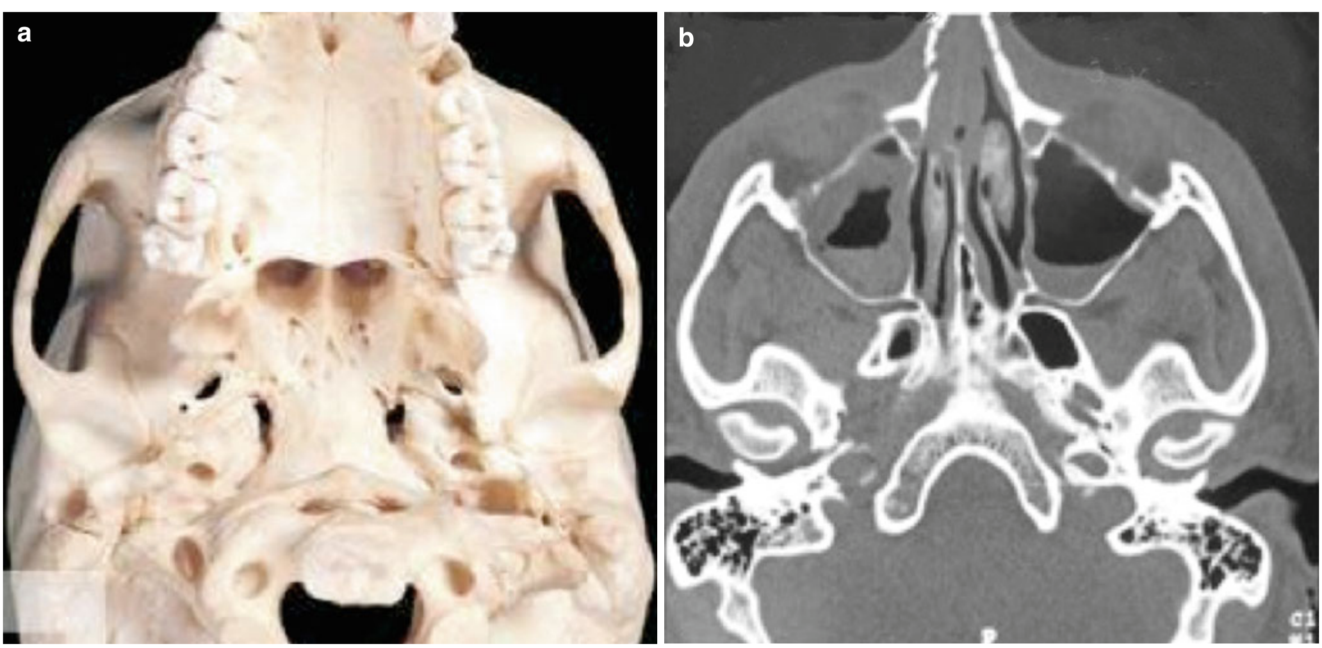

Fig. 8.102 Normal anatomy of the zygomatic arch (**a**, **b**)

Fig. 8.103 A minimally buckled arch. Very suitable for closed reduction

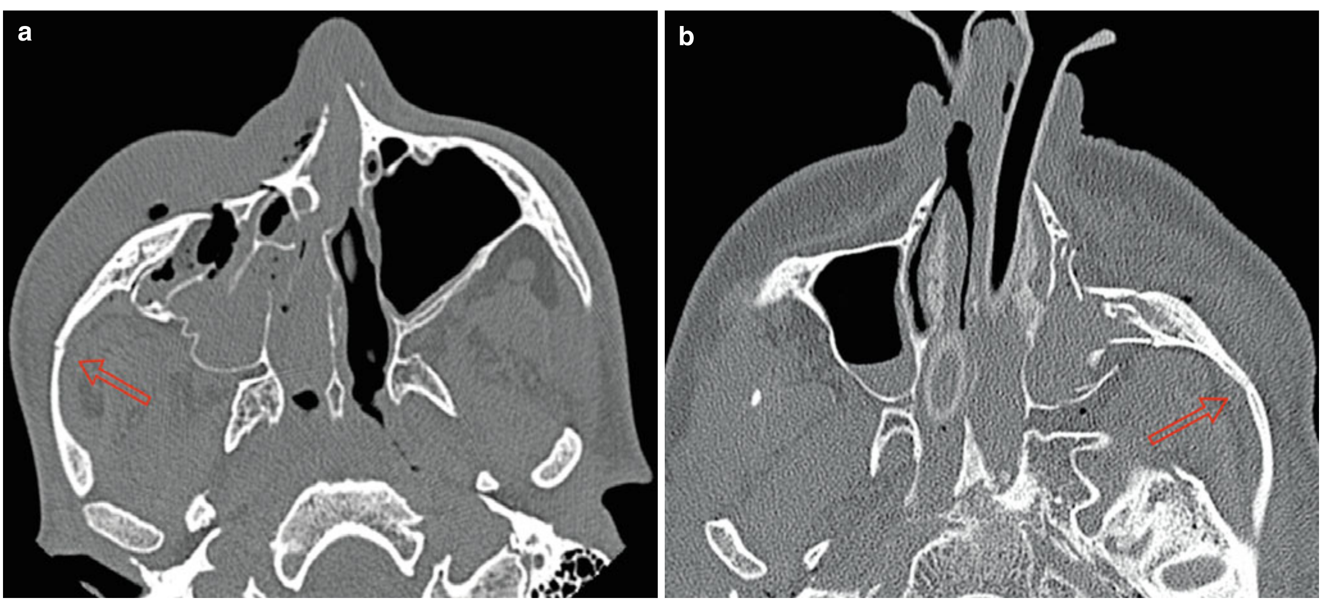

Fig. 8.104 Severe bowing of the arch with an associated fracture (**a**, **b**). These cases need careful assessment both preoperatively and during surgery. Not all require open reduction and fixation. The arch can often be aligned and supported using anterior fixation of the zygoma as previously described. But this is not guaranteed and the arch fractures can displace laterally, resulting in an increase in transverse facial width. Be prepared to plate these if necessary

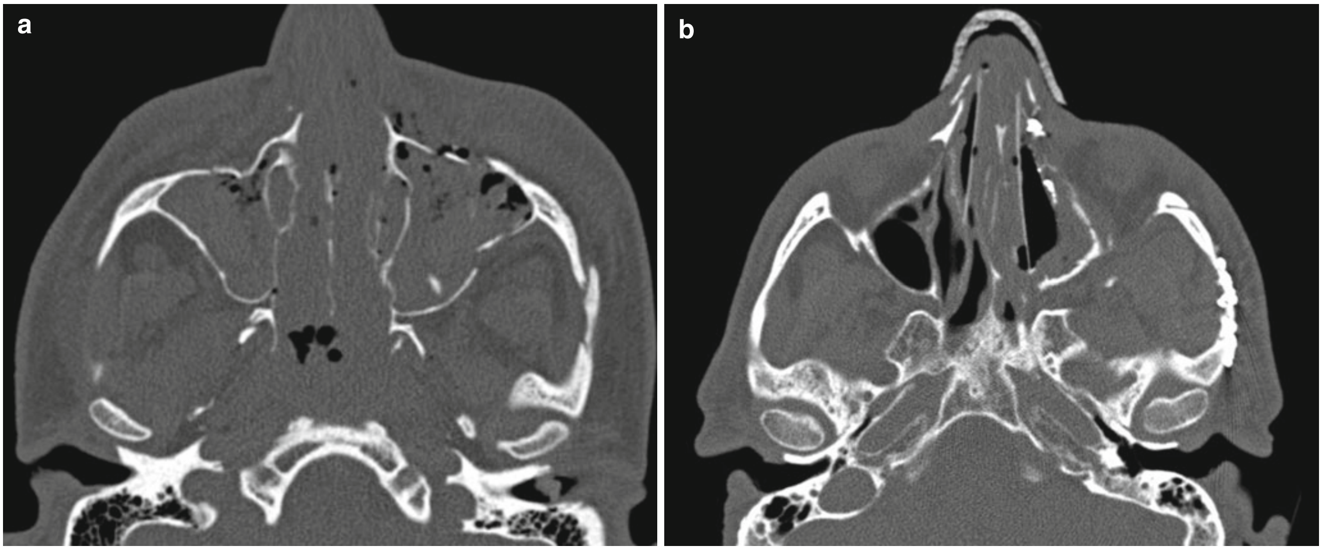

Fig. 8.105 Telescoping of the arch with segmentation often requires repair (**a**, **b**)

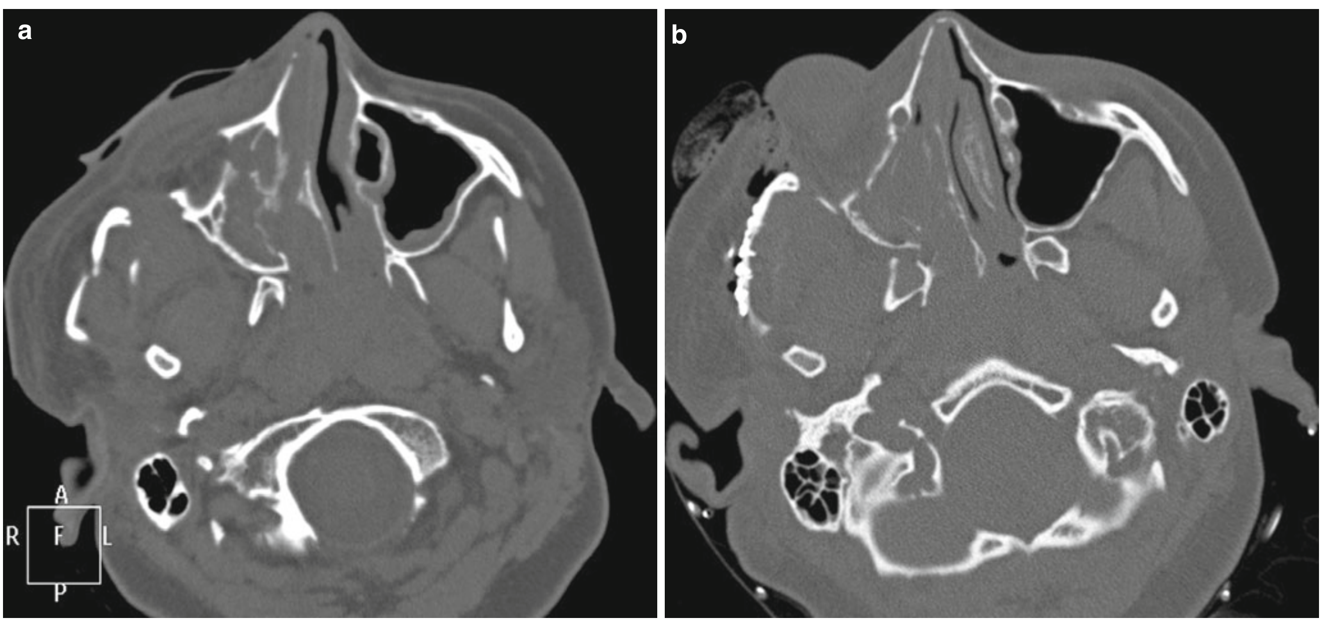

Fig. 8.106 Severe injury to the arch and ZMC (**a**). Repair is essential for a good result (**b**)

8.7.1 Arch Exposure

Repair of the arch requires an additional, posterior incision and dissection along the arch, significantly adding to the operative time and placing the facial nerve at risk from injury. Although a coronal flap will provide good exposure along the entire arch, many surgeons consider this an excessive approach, if there are no other fractures requiring access through this flap. An alternative approach is the "question mark" or "inverted hockey stick" incision, extending upwards from the tragal region into the temple. This approach is similar to the preauricular component of the coronal flap. The incision is initially deepened to the temporalis fascia and posterior end of the arch. The fascia is then incised and reflected forward, along with the periosteum over the arch, gradually working along its length.

8.7.1.1 Inverted Hockey Stick Exposure

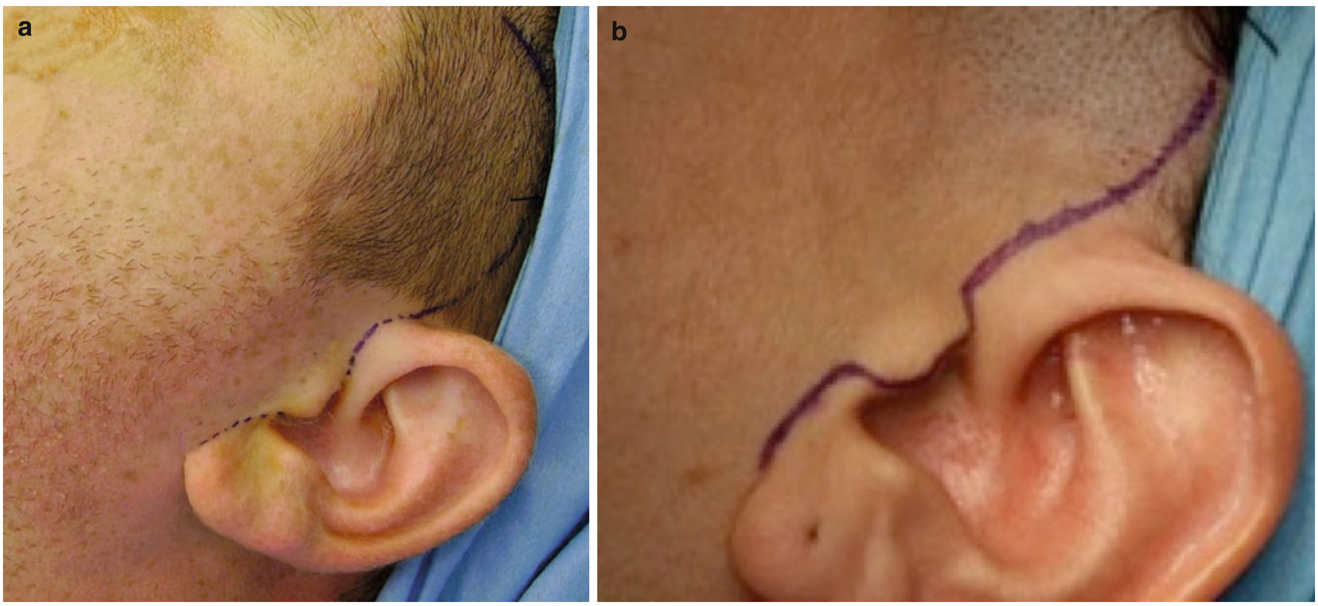

Fig. 8.107 The inverted hockey stick incision extends from the preauricular region into the temporal scalp (**a**, **b**). The aim is to raise a full-thickness layer that includes the temporalis fascia. Dissection in this plane will come down onto the arch

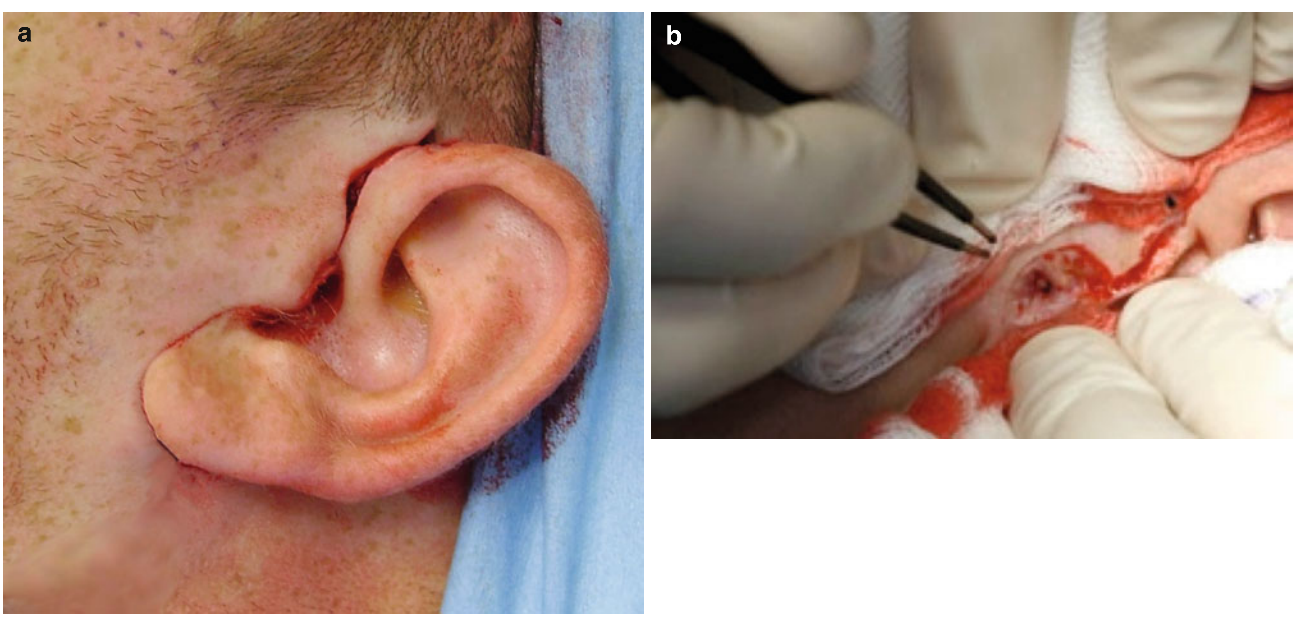

Fig. 8.108 The incision can be taken in front or around the tragus to hide the scar (**a**). An initial full-thickness skin flap is raised (**b**)

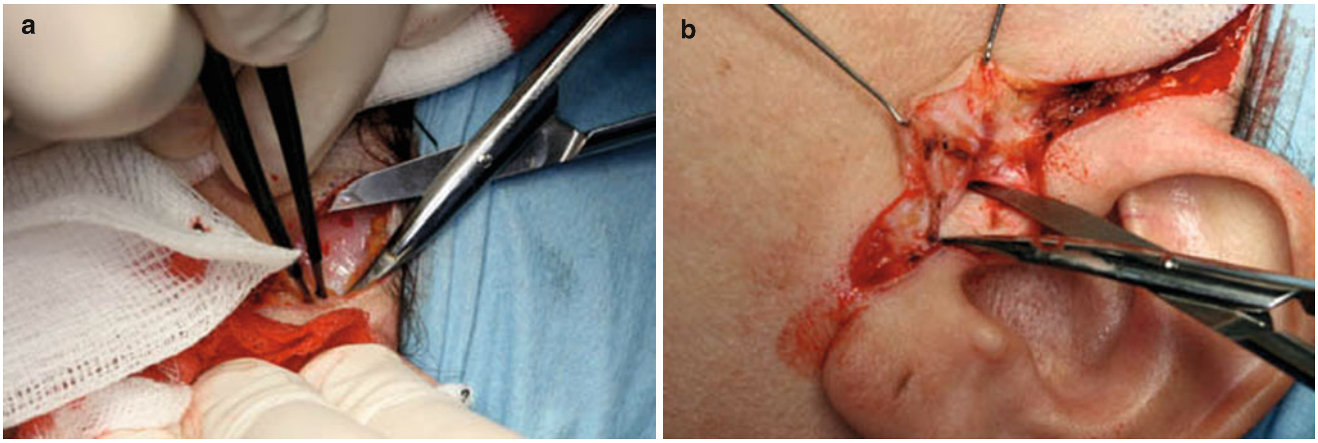

Fig. 8.109 Dissection proceeds down the avascular plane just in front of the tragus (**a**). This exposes the base of the zygomatic arch, where the periosteum is incised (**b**)

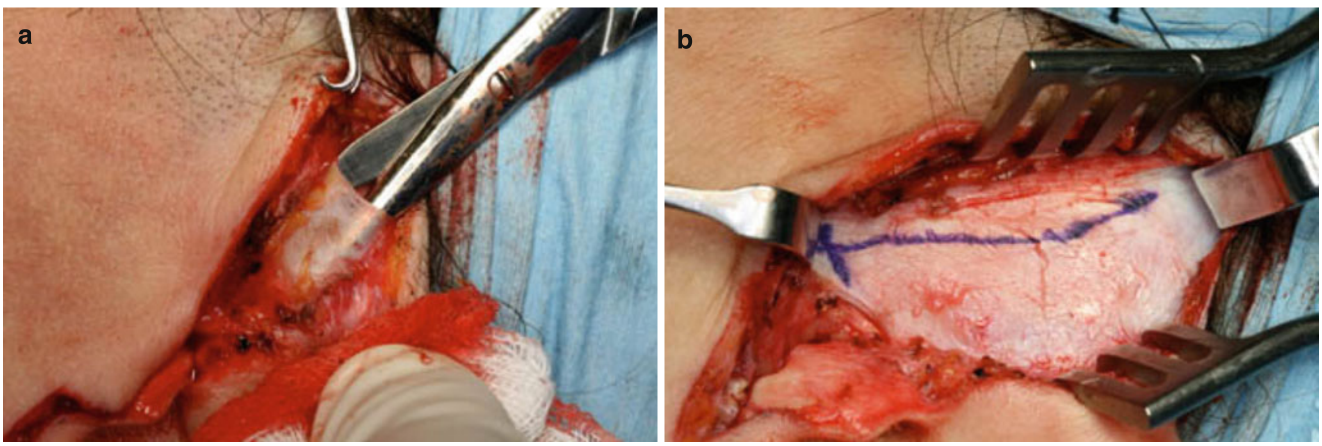

Fig. 8.110 The skin incision is then extended upwards into the scalp, deepened and reflected, to expose the temporalis fascia (**a**). Here it has been marked in preparation for an incision later on (**b**)

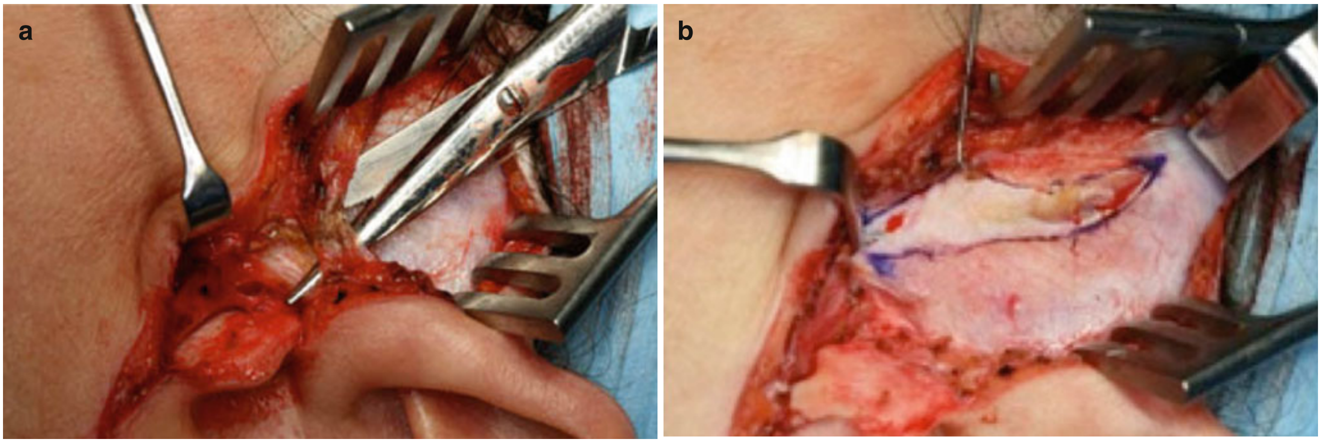

Fig. 8.111 All intervening tissue is divided to expose the entire posterior temporalis fascia as it passes down to attach along the zygomatic arch. Since this level of dissection is only slightly anterior to the tragus, the facial nerve should be safe. The fascia is then incised. The key to this approach is to get under the fascia - then the nerve will remain protected. In some patients there is sufficient fat between the superficial and deep layers of fascia to allow dissection between the two. In others, the entire fascia must be raised off the muscle to ensure the correct plane of dissection. This entire skin-fascial flap is reflected forwards to expose the postero-superior aspect of the arch

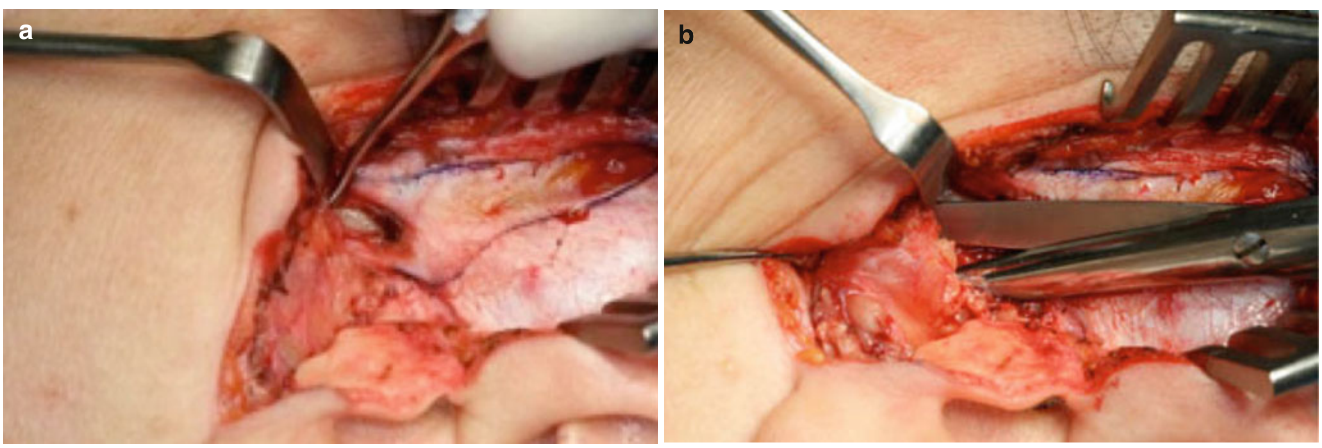

Fig. 8.112 The periosteum is elevated off the arch as the flap is reflected forwards. Tissues below the arch may also need to be mobilised. These are dissected off the capsule of the joint. By remaining within this plane the facial nerve should remain protected

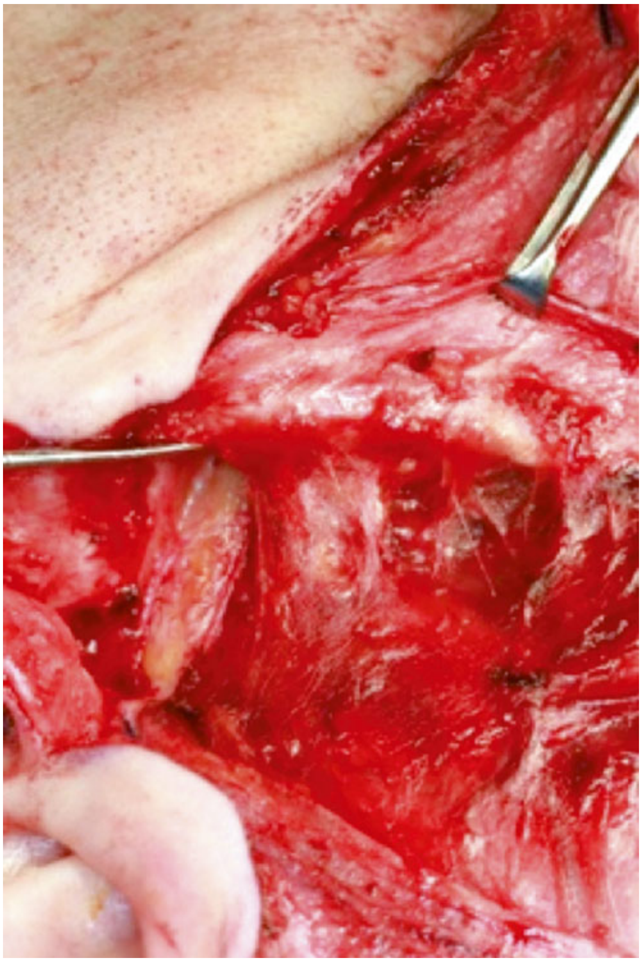

Fig. 8.113 Forward reflection of the entire tissue mass exposes the arch. A fair amount of retraction by an assistant is often necessary, but this must not be excessive. Otherwise the facial nerve can be damaged

This approach provides excellent access to the posterior half of the arch, but because of the relative remoteness of the incision, fractures further forwards are harder to reach and repair. The further forwards the dissection needs to go, the greater the upper extension of the temple incision needs to be. Heavy retraction should be avoided to minimise the risk of traction injury to the upper branches of the facial nerve.

8.7.1.2 Two-Way Access to the Arch

In the example shown (see Figs. 8.114–8.118), a high-impact injury resulted in a comminuted fracture of the zygomatic arch with considerable telescoping of the fragments and a free-floating segment of bone. A coronal flap was not required. Access to the posterior half of the arch was obtained through an inverted hockey stick incision. Access to the anterior half of the arch was possible through an infraorbital incision (which was required for repair of the infraorbital rim and orbit).

Unfortunately, the floating fragment was between the limits of access of these two approaches and internal fixation was not possible through either one. Because of the restricted access and heavy retraction required for exposure of the entire arch, the floating fragment of bone was first secured to a long plate approximately midway along its length. This plate was then used to manipulate the fragment into the correct position using both ends of the plate as they emerged from the anterior and posterior incisions. The floating fragment was first anatomically fixed to the zygoma through the anterior incision. Once secured, the mobile zygomatic complex was manipulated forward to anatomically align the zygomatic arch. The remaining posterior screws were then placed through the posterior incision. Once secured, the ends of the plates were then shortened accordingly.

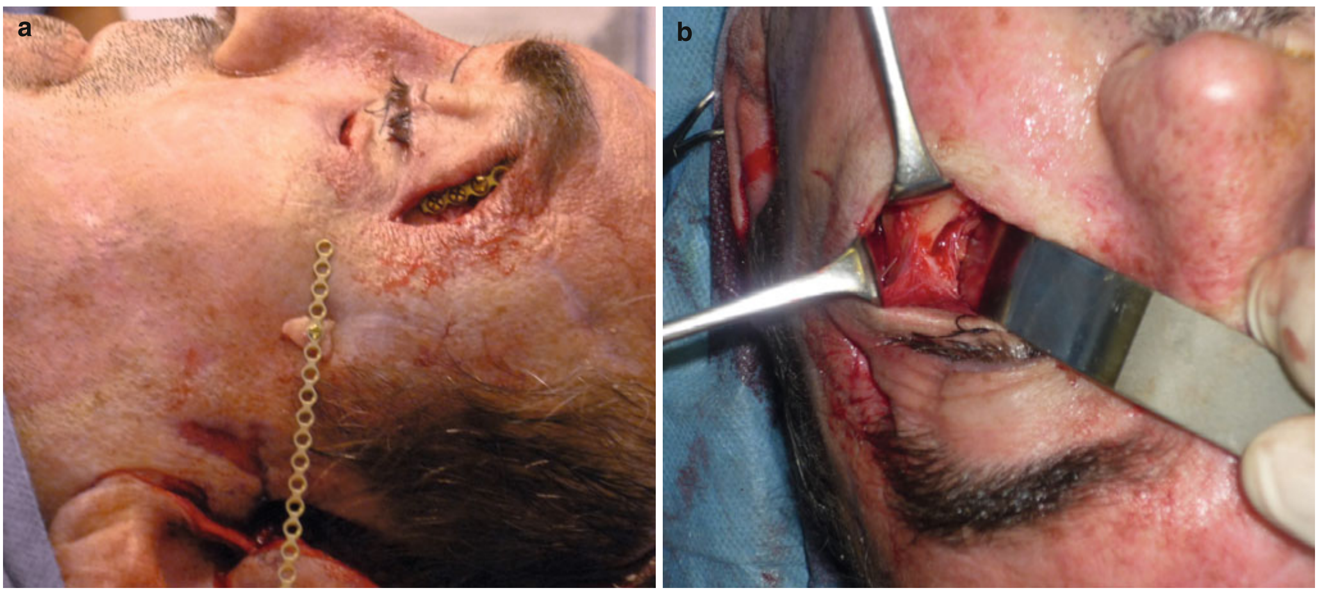

Fig. 8.114 Access to the midpoint of the arch is difficult due to the remoteness of the skin incisions. To secure a fragment, a "through and through" approach may be possible (see text) (**a**, **b**)

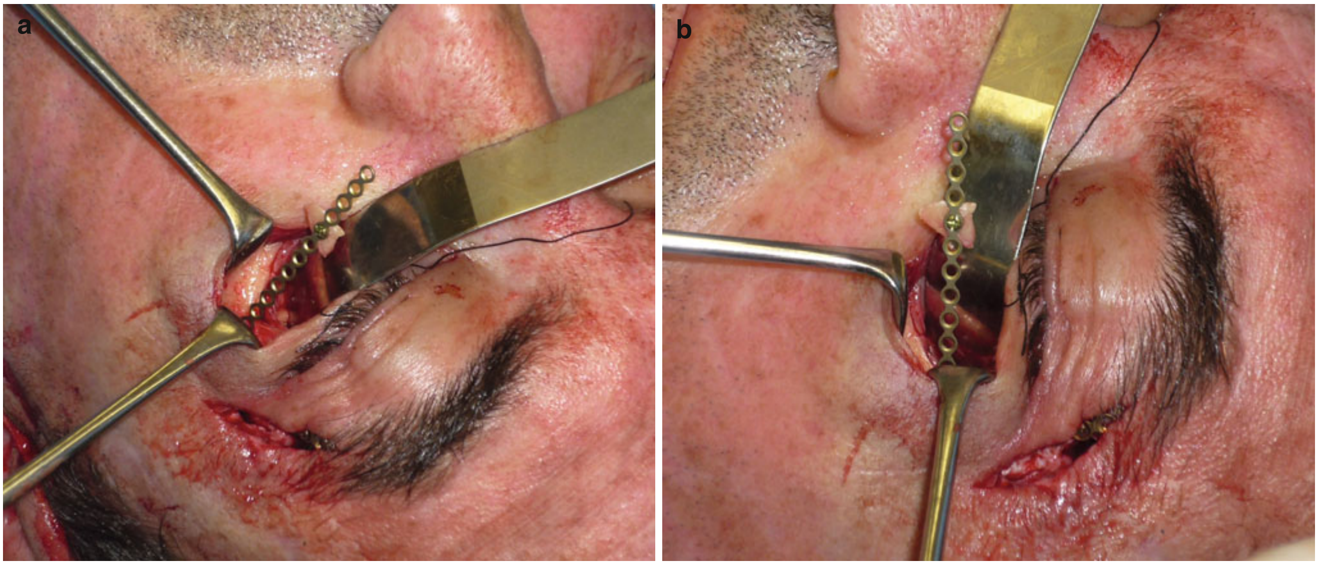

Fig. 8.115 The fragment is secured to a plate, which is passed along the entire arch and brought out through both incisions, anteriorly and posteriorly (**a**, **b**)

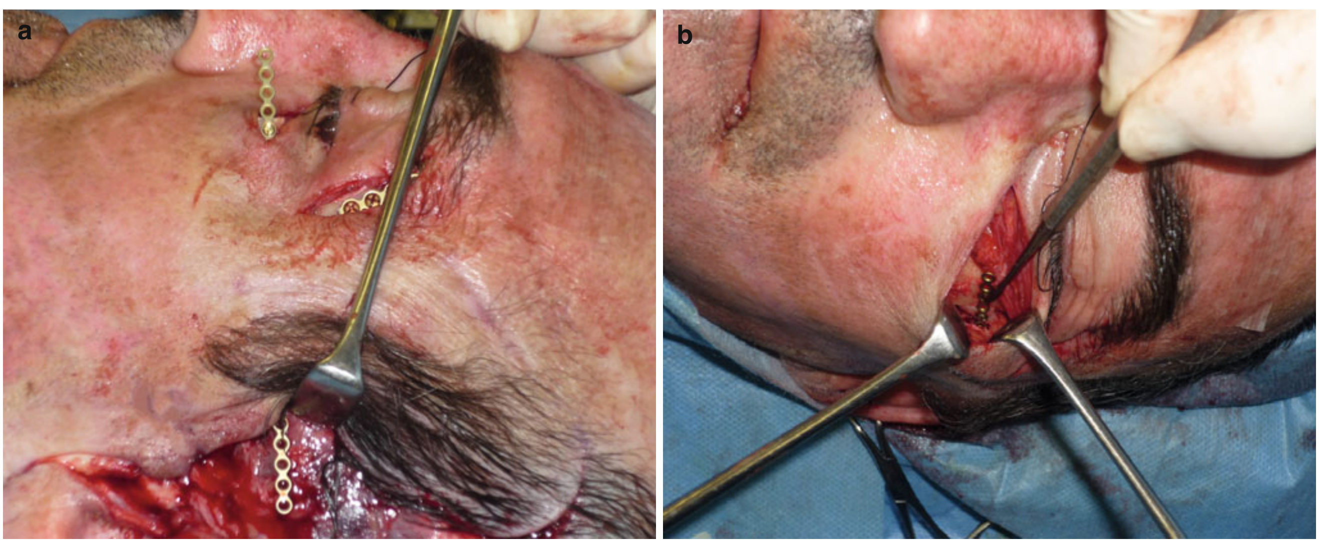

Fig. 8.116 Once in the correct position (**a**), the fragment is plated to the anterior bone through the infraorbital incision (**b**)

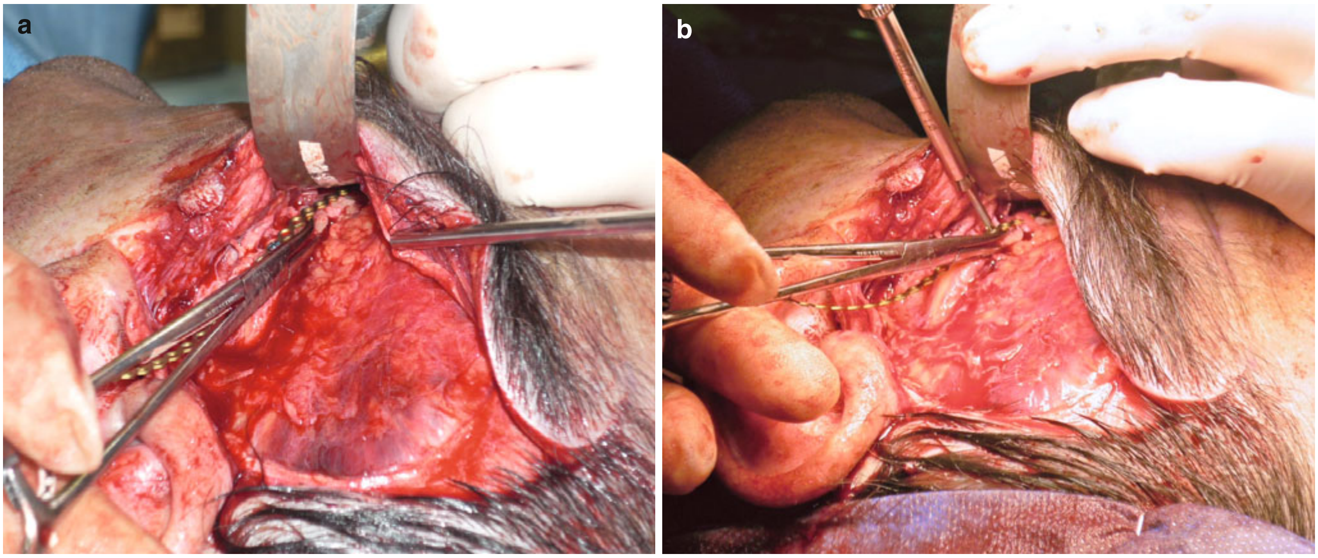

Fig. 8.117 The ZMC is elevated (**a**) and the plate secured posteriorly (**b**)

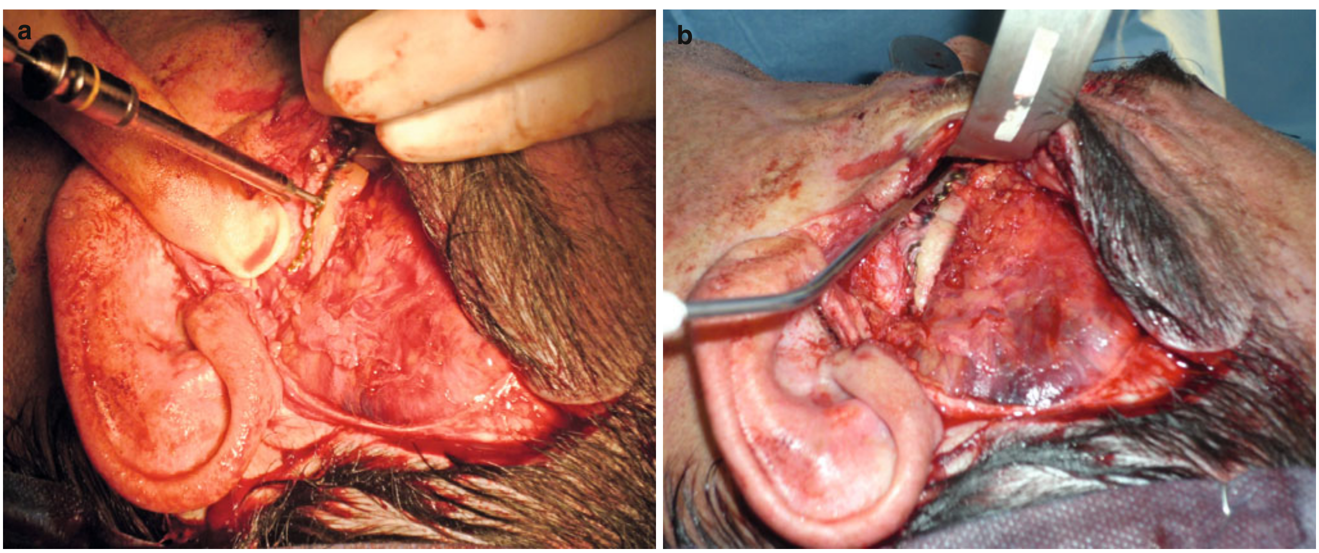

Fig. 8.118 Excess plate is then trimmed. This technique avoids the heavy traction often required to access the middle of the arch (**a**, **b**)

8.7.1.3 Direct Transcutaneous Approach

A direct transcutaneous approach has the advantages of being a much smaller and quicker approach, but does involve making an incision in the skin over the arch, with the risks of unsightly scarring and injury to one of the branches of the facial nerve. Nevertheless, experience in the repair of condylar fractures has shown that encountering these nerves is not a high risk to them, so long as they are adequately protected. This approach is best suited for fractures midway along the arch where conventional approaches require extensive dissection and retraction to reach the fracture.

This technique follows the same principles as the transcutaneous approach to the condyle. Following review of the patient's imaging (ideally a CT scan) and clinical examination, the fracture site is marked on the skin. The incision is marked in a suitably sited skin crease, approximately 1.5 cm in length. Following a full-thickness incision of the skin only, deeper dissection then proceeds, using pointed scissors or tenotomy scissors. The underlying fascia and tissues are carefully separated by blunt dissection, heading towards the fracture. By dissecting in a direction parallel to the course of the nerve it is less likely that it will be encountered or injured. Gently dissect at multiple sites along the whole length of the incision, so as to mobilise the underlying tissues widely. This helps with tension-free retraction, reducing the likelihood of traction to the nerve (see Figs. 8.119–8.123).

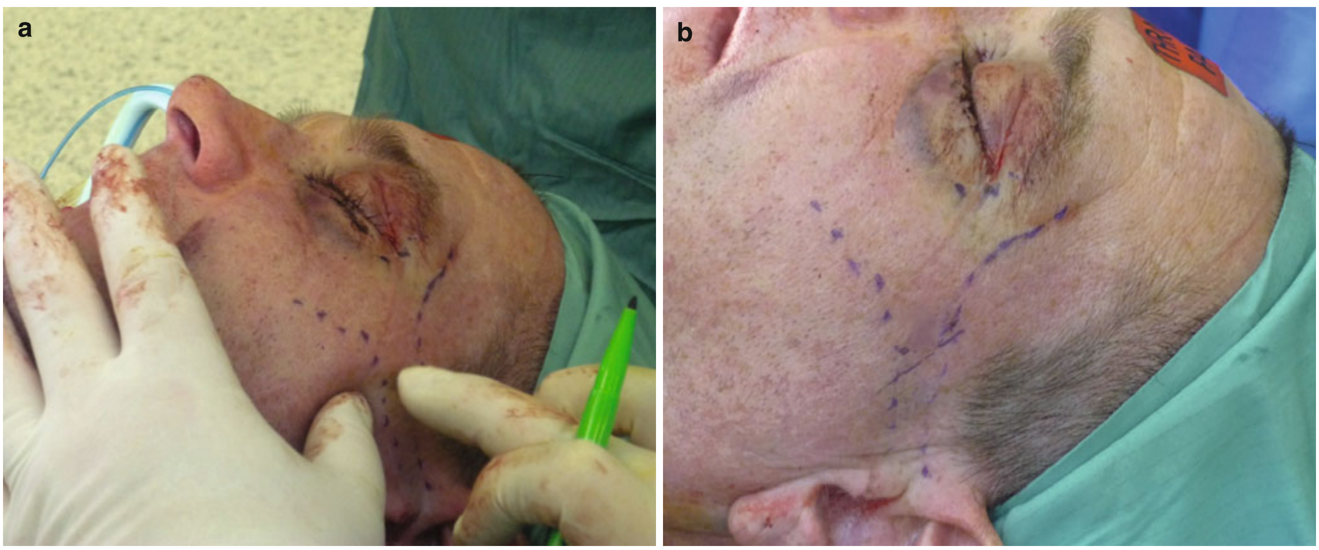

Fig. 8.119 Direct access to the midpoint of the arch combines our experiences of condylar repair with those of aesthetic surgery. With correct technique, the risks to the facial nerve are very small. The incision is marked in a suitable skin crease (**a**, **b**)

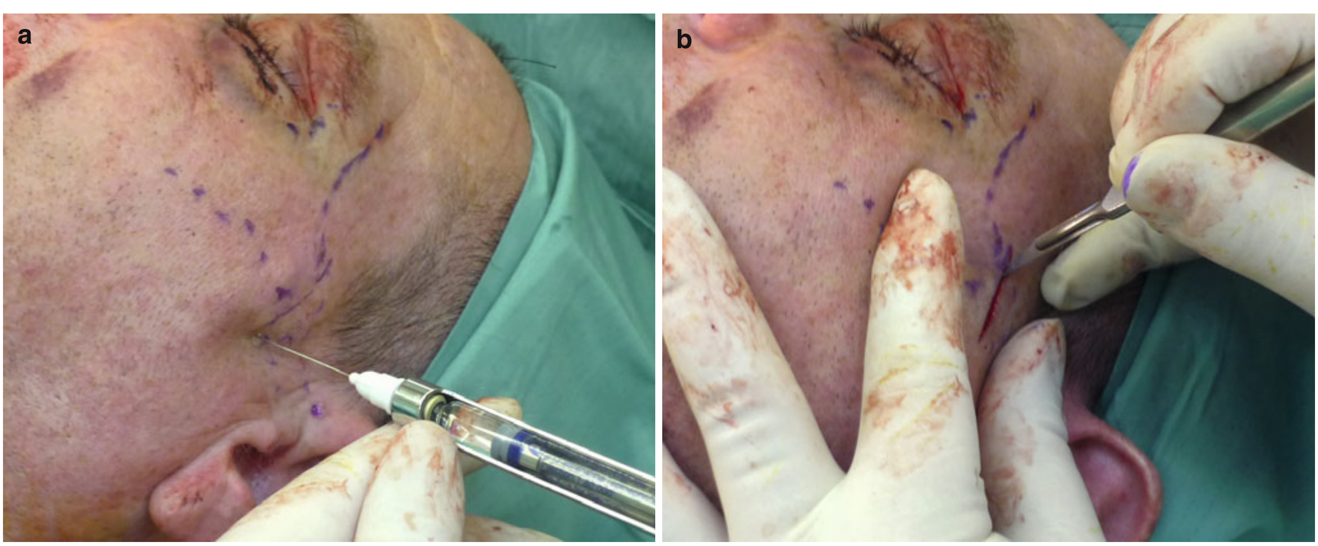

Fig. 8.120 Following placement of local anaesthetic (**a**), a full-thickness skin incision is made (**b**)

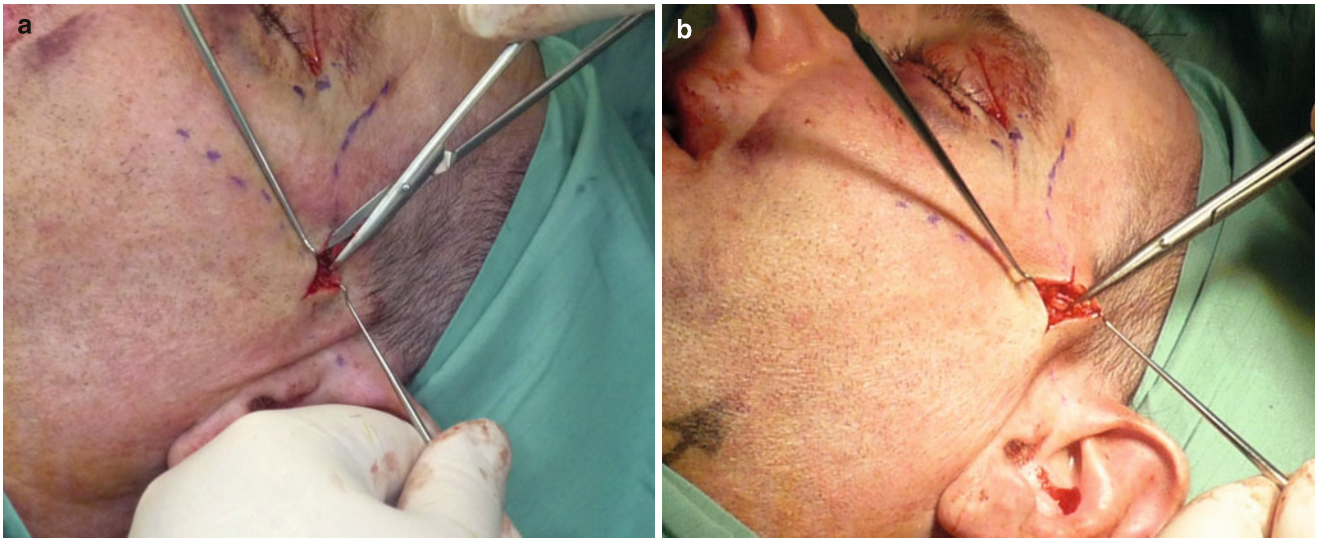

Fig. 8.121 Blunt dissection then carefully approaches the bone (**a**, **b**)

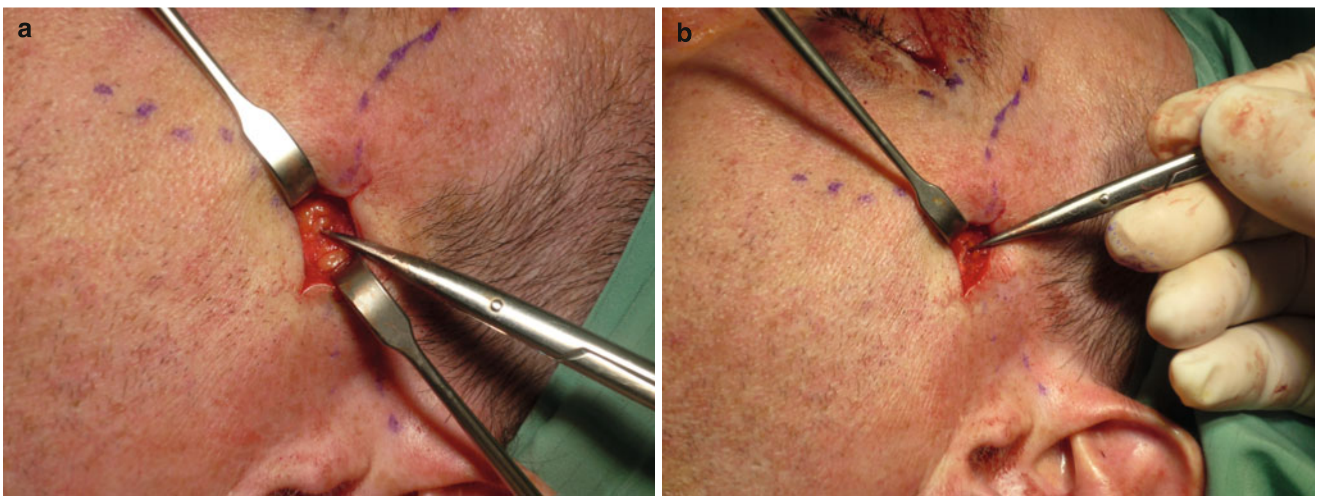

Fig. 8.122 The nerve is frequently encountered (**a**). It is gently repositioned and protected (**b**)

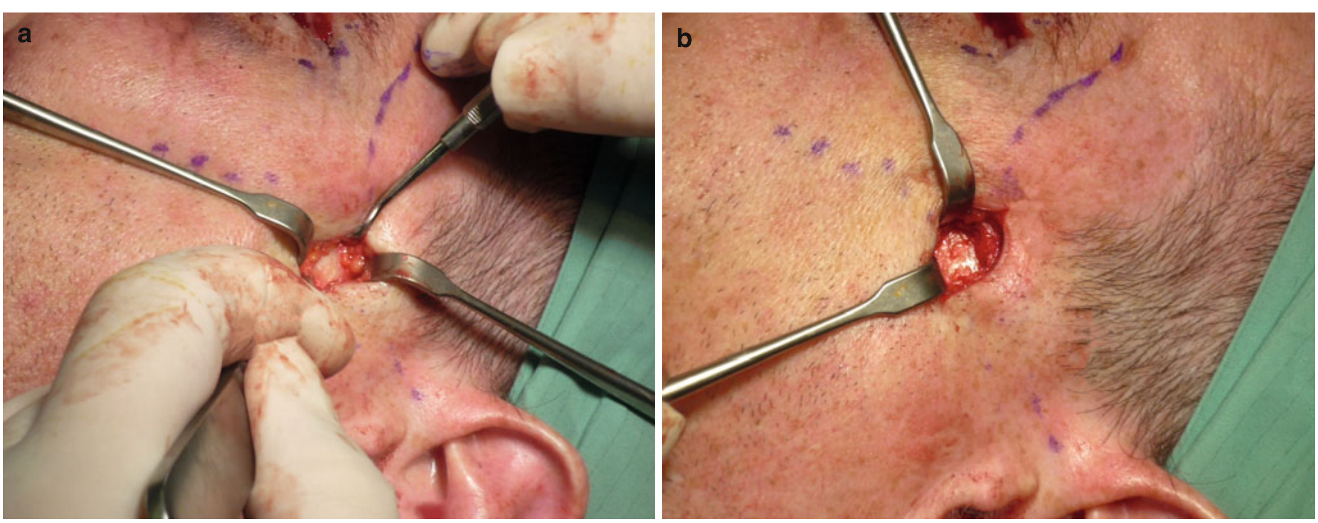

Fig. 8.123 The periosteum is then incised (**a**) and elevated (**b**)

Once the arch and fracture have been clearly identified, the periosteum is incised and elevated. With careful retraction and dissection, a surprising amount of exposure is possible. The fracture can then be repaired. With floating fragments, careful orientation of the plate along the bone is required. Often it is best to secure the plate onto the floating fragment first and then manipulate this into position before placing the remaining screws (see Figs. 8.124, 8.125 and 8.126).

Following fixation, the wound is close in layers. With good aftercare, a very satisfactory scar is possible (see Figs. 8.127, 8.128 and 8.129). Salivary fistula is rare.

Fig. 8.124 The fracture is reduced and a plate chosen (**a**, **b**)

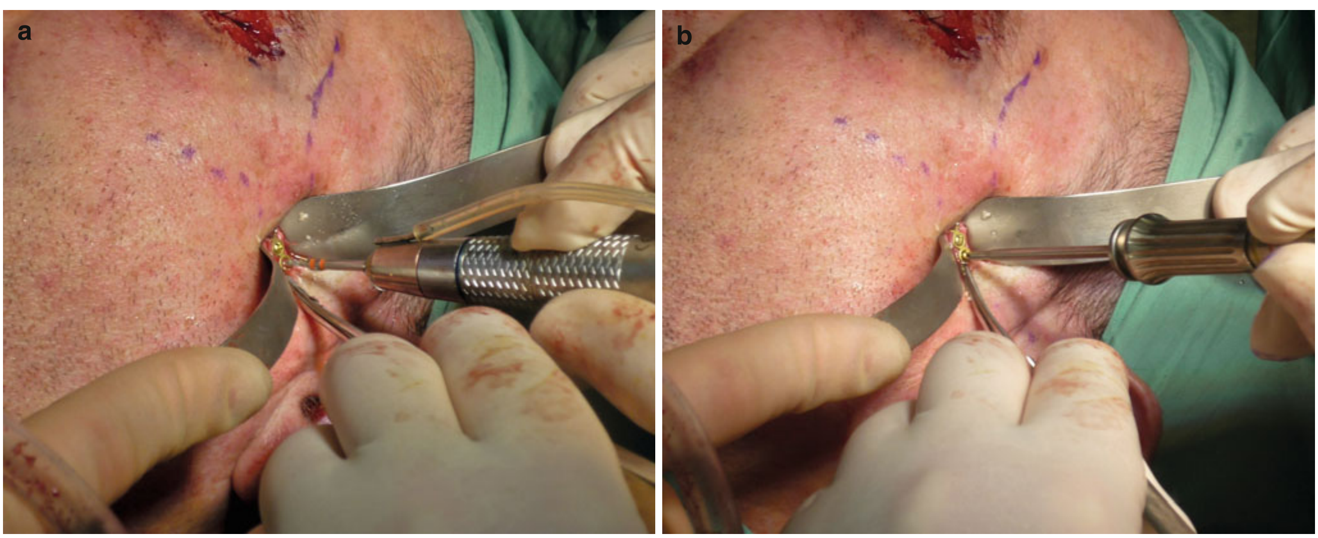

Fig. 8.125 The plate is then secured, protecting the tissues throughout (**a**, **b**)

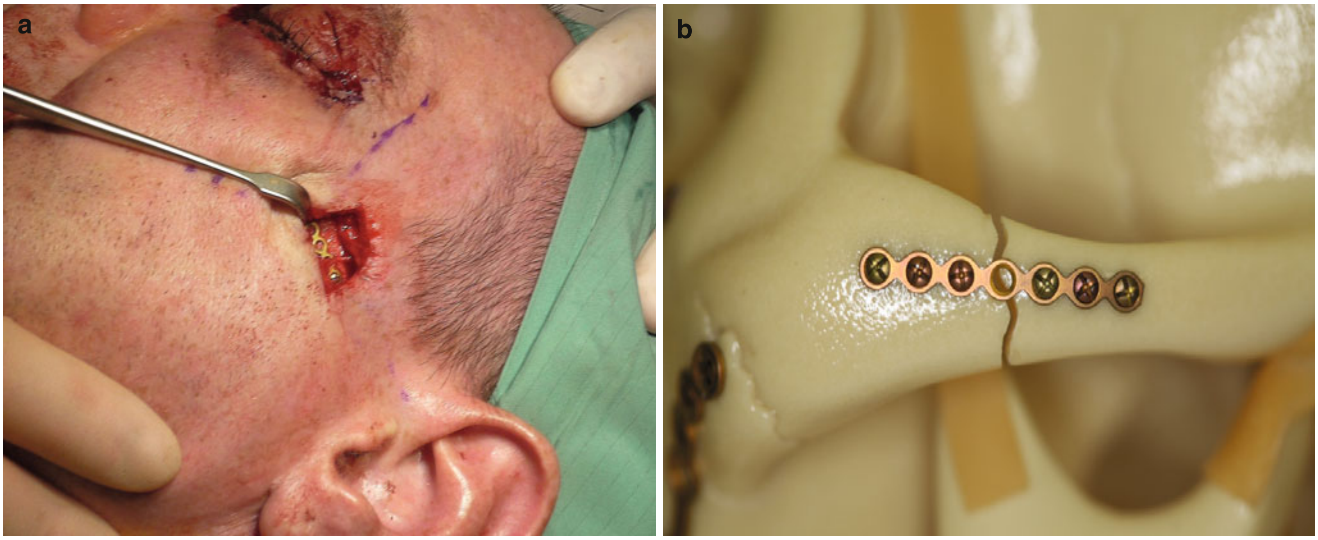

Fig. 8.126 This technique is best suited for fractures that are difficult to access through conventional approaches (**a**, **b**). It is also quick and saves time

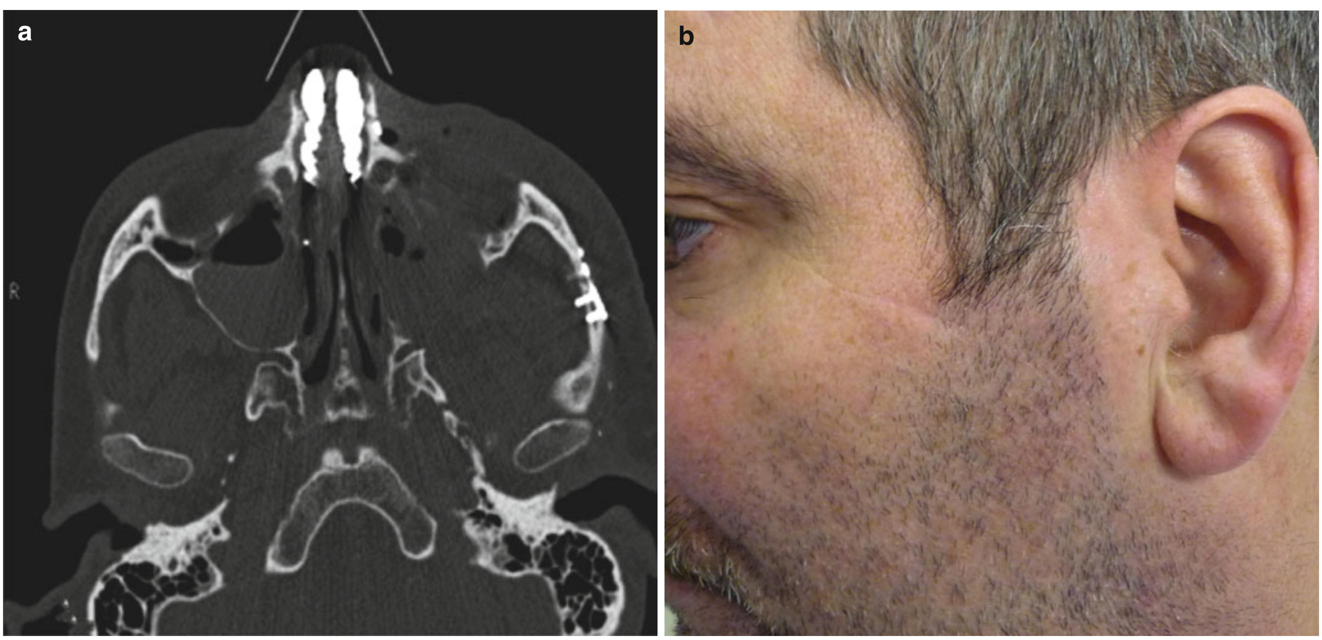

Fig. 8.127 Postoperative CT (**a**) and wound at 3 months (**b**)

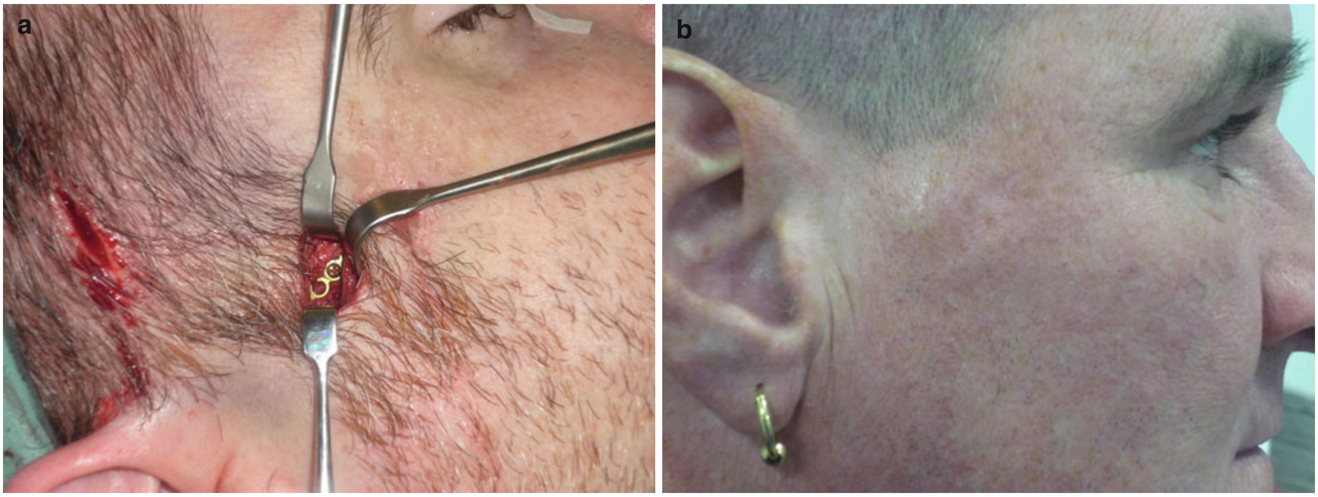

Fig. 8.128 Another example with wound at 3 months (**a**, **b**). Usually these heal very well

Fig. 8.129 This patient declined a coronal flap for his extensive injuries. Repair was undertaken through local incisions. The wound healed well and there was no weakness of the facial nerve (**a**–**c**)

8.8 When Do We Need Wider Access?

Although local incisions provide sufficient access to much of the ZMC, on occasion repair through a coronal approach is justified. This may be required when there is extensive damage to the zygomatic arch and body, or when there are coexisting fractures in the upper midface. A "hemi" coronal or "three quarter" coronal flap may provide sufficient exposure to facilitate repair. Certainly this is considerably better exposure than that gained through local incisions. It allows direct visualisation of the entire arch and lateral orbital wall, as well as facilitating a more posterior placement of the FZ plate (which may otherwise be palpable postoperatively) (see Figs. 8.130 and 8.131).

Fig. 8.130 This patient was kicked in the face by a horse. Her right globe was ruptured. The globe was enucleated and the external wound repaired prior to transfer. In addition to the globe and soft tissue injuries, there was major disruption to the ZMC with involvement of the maxilla and avulsion of the medial canthus. This was clearly not suitable for minimal access repair (**a**–**c**)

Fig. 8.131 Postoperative CT and clinical appearances (**a**–**c**). Repair was undertaken through the original wound combined with a coronal flap

Case 1

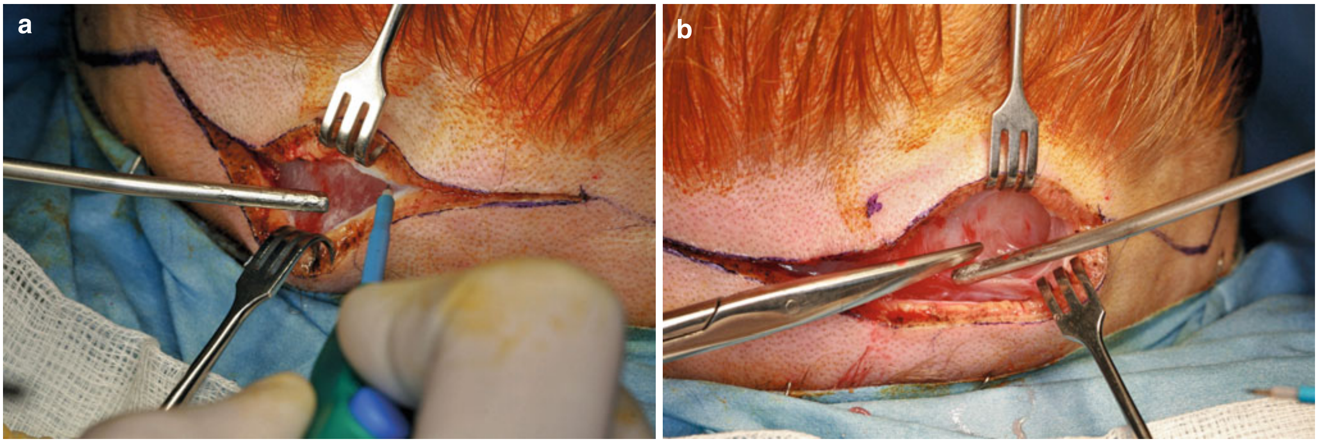

Fig. 8.132 The coronal flap is occasionally required for complex injuries to the ZMC (**a**, **b**). This technique is described in detail in Chapter 13

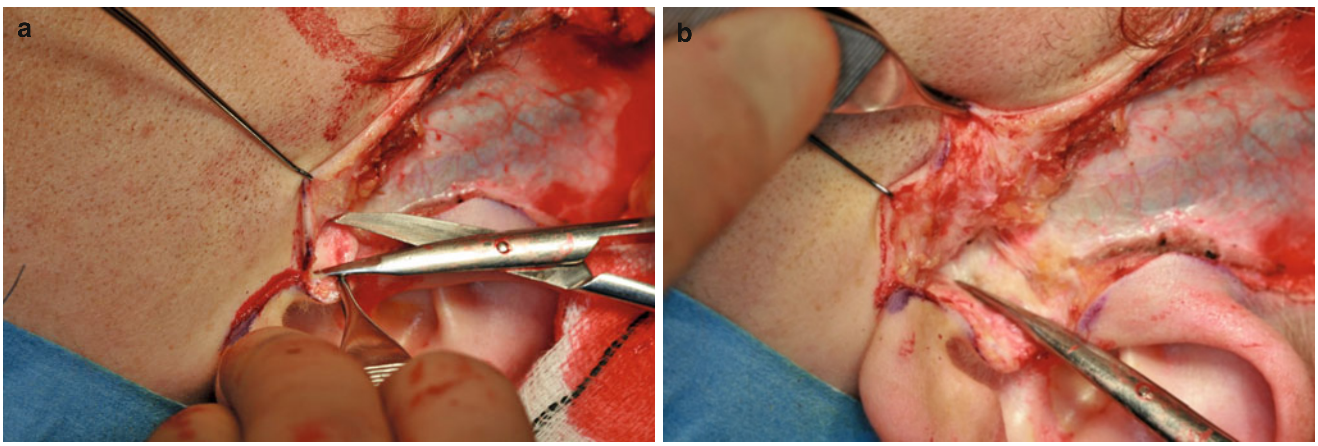

Fig. 8.133 Left preauricular dissection (**a**, **b**)

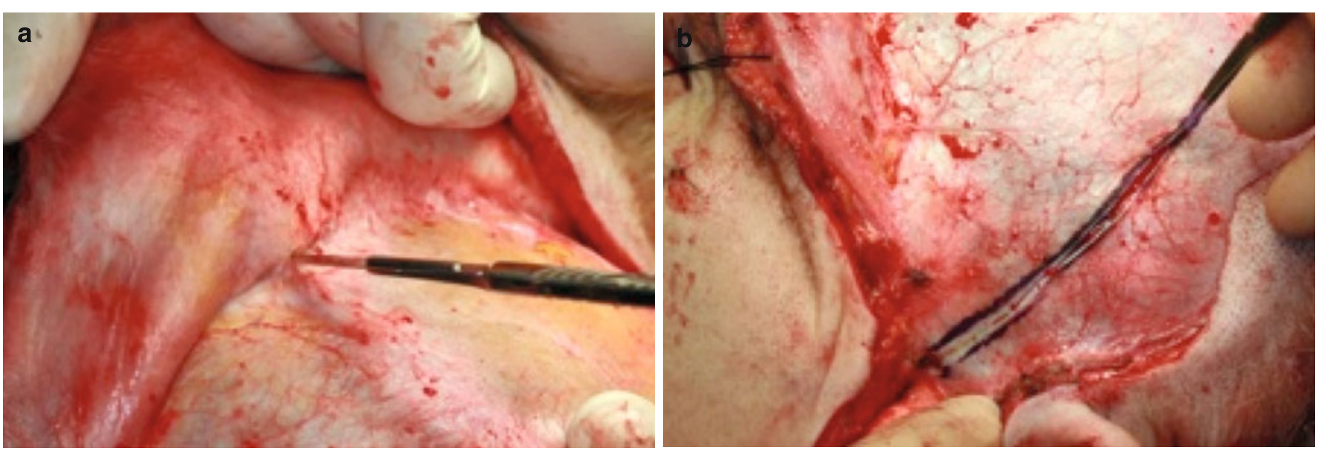

Fig. 8.134 The flap is partly reflected and the temporalis fascia incised prior to further reflection (**a**, , **b**)

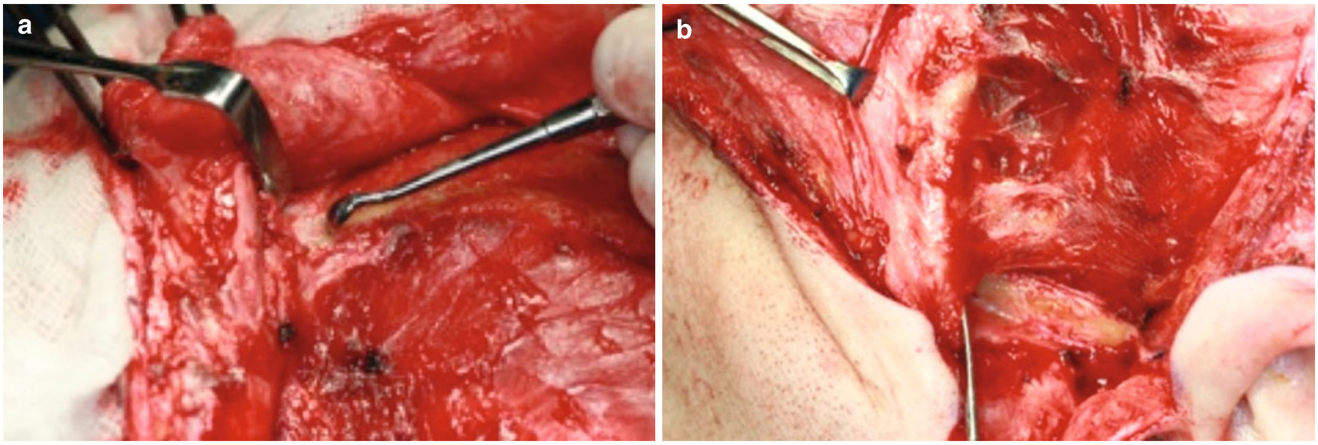

Fig. 8.135 Simultaneous subperiosteal dissection along the left frontal process of the zygoma and arch are undertaken (**a**, **b**)

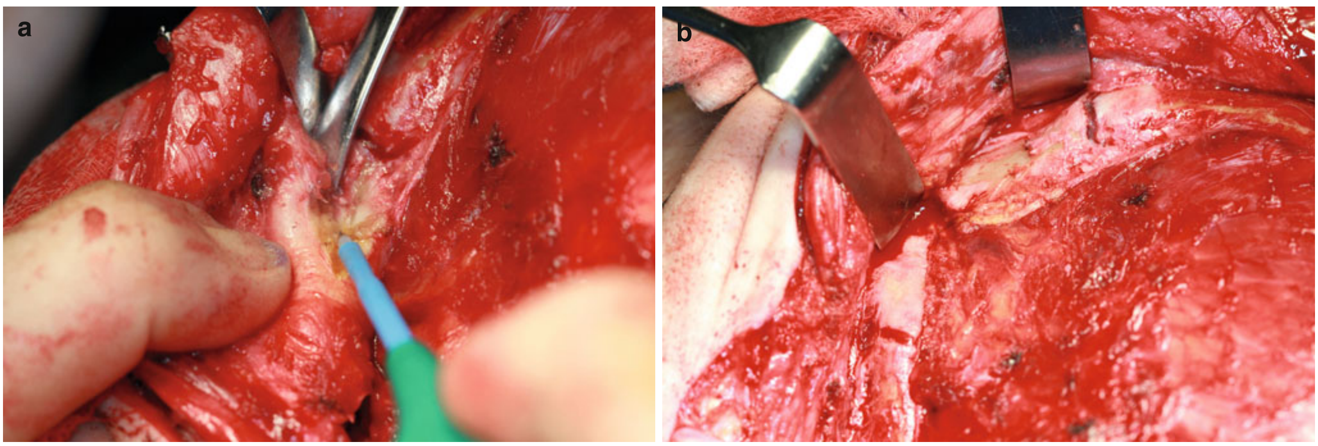

Fig. 8.136 The dissection proceeds along the entire length of the arch to expose the arch, body, and frontal process (**a**, **b**)

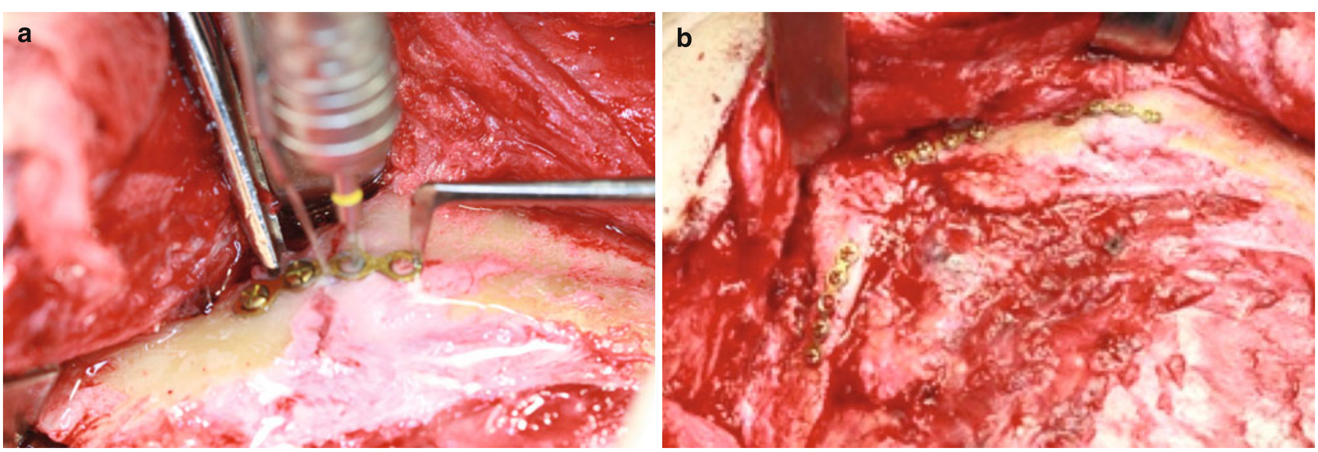

Fig. 8.137 Fracture fixation (**a**, **b**)

Case 2

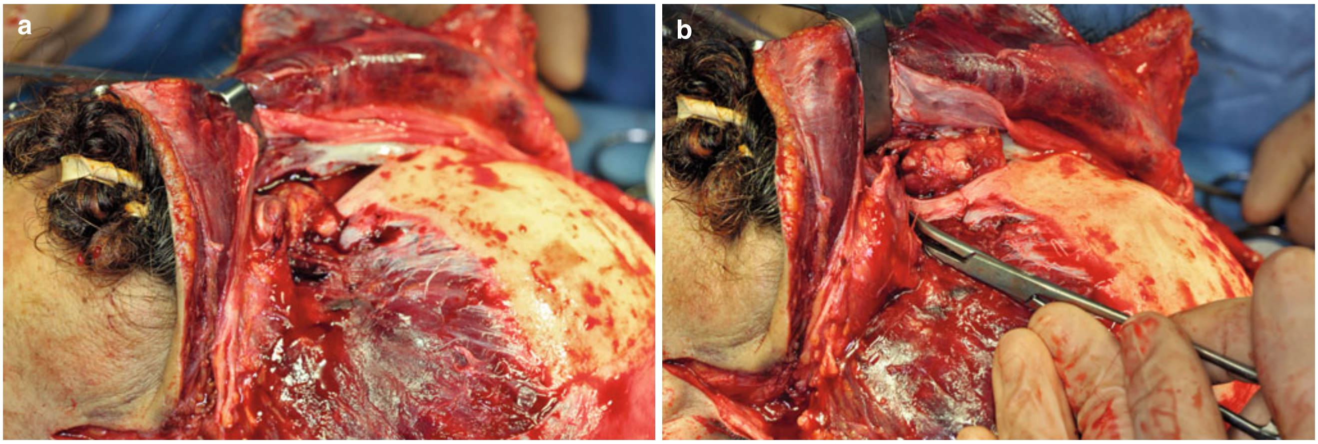

Fig. 8.138 Extensive left-sided fractures are exposed. The FZ suture was very displaced but could be reduced (**a**, **b**)

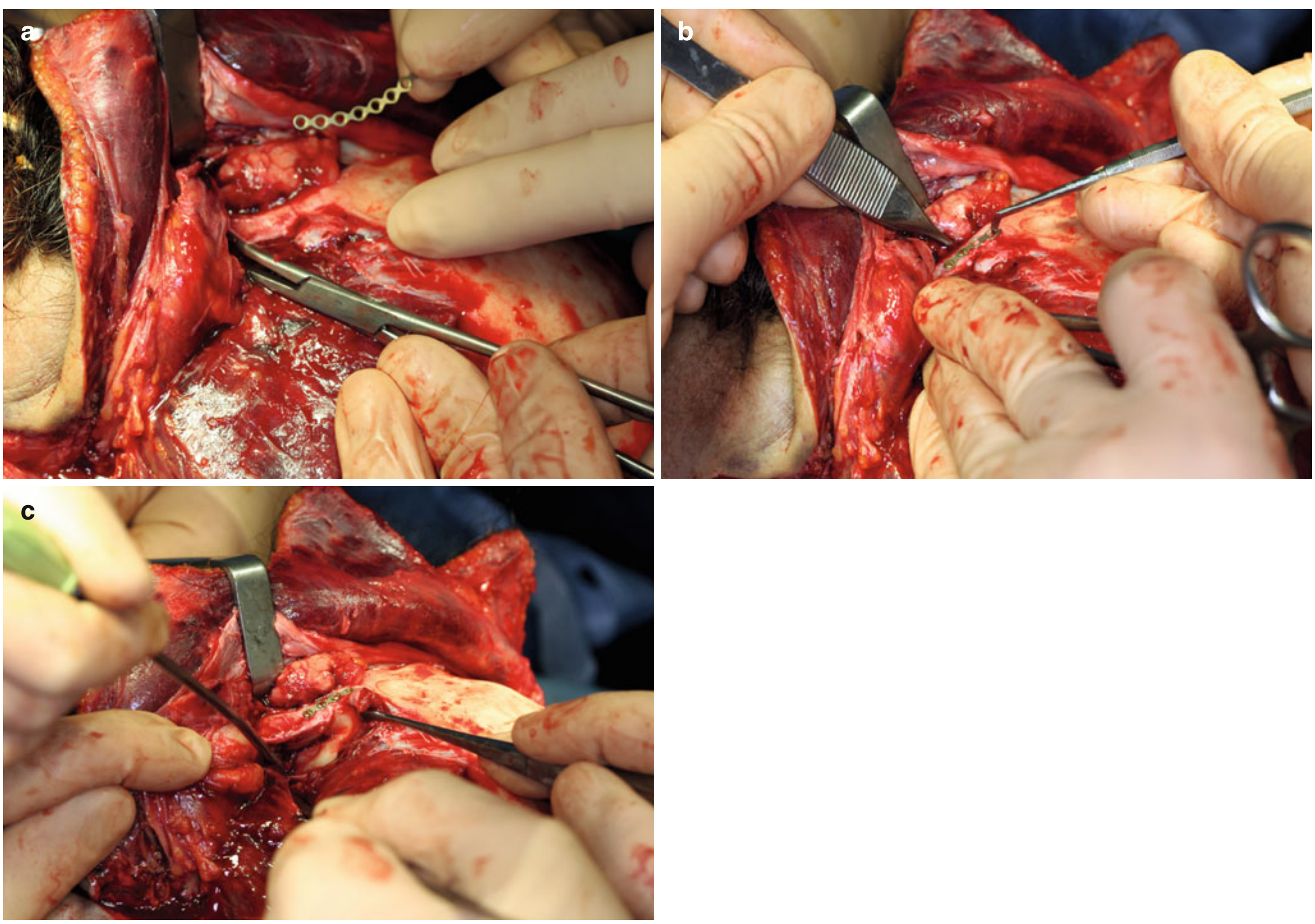

Fig. 8.139 Fixation of the FZ suture (**a**–**c**)

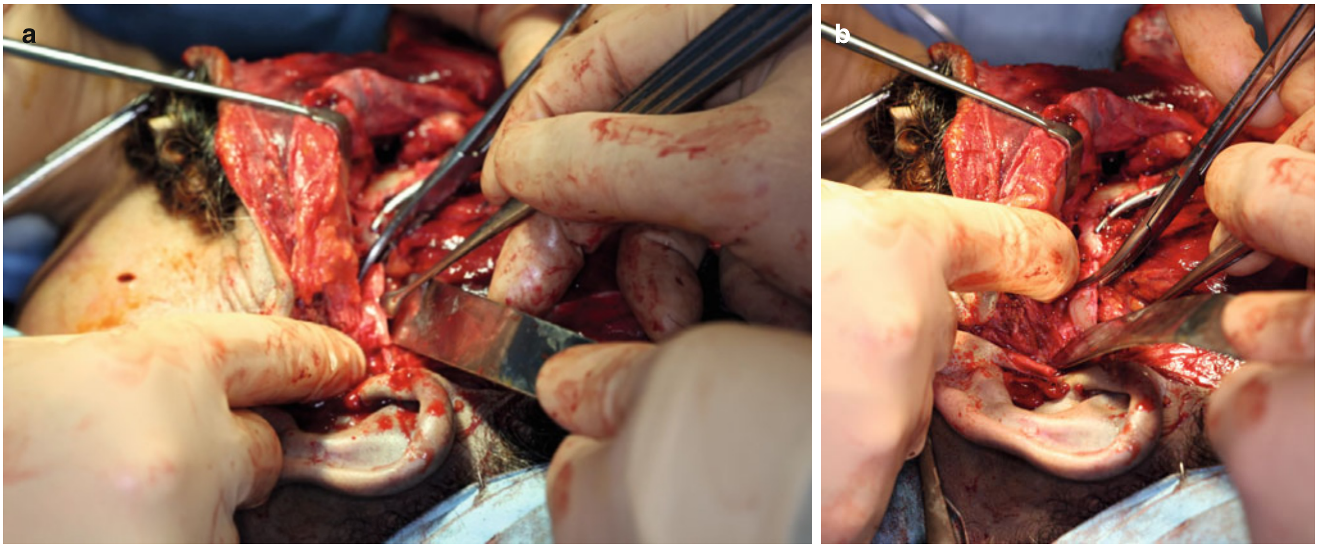

Fig. 8.140 Repair of the comminuted arch (**a**, **b**)

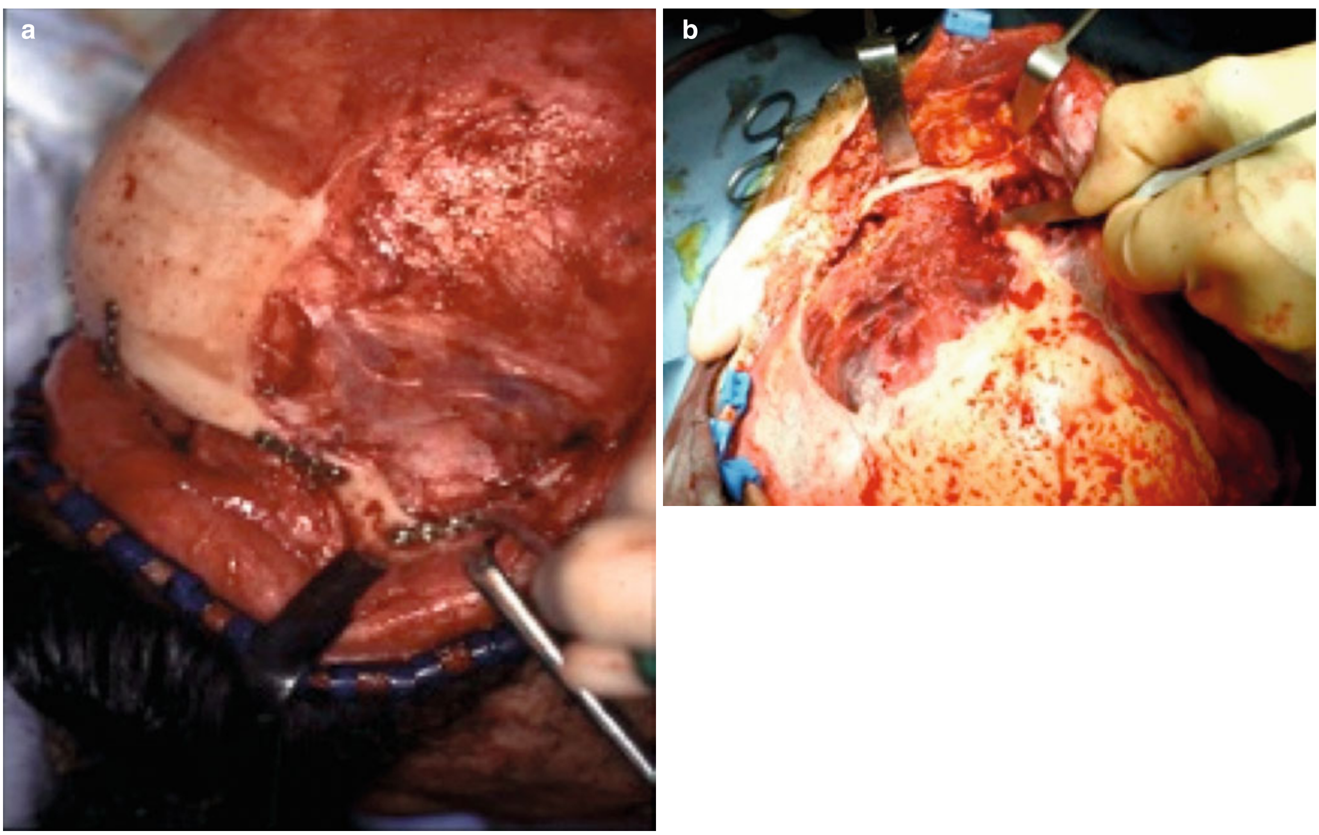

Fig. 8.141 Two further examples. A well-raised flap can provide excellent access (**a**, **b**)

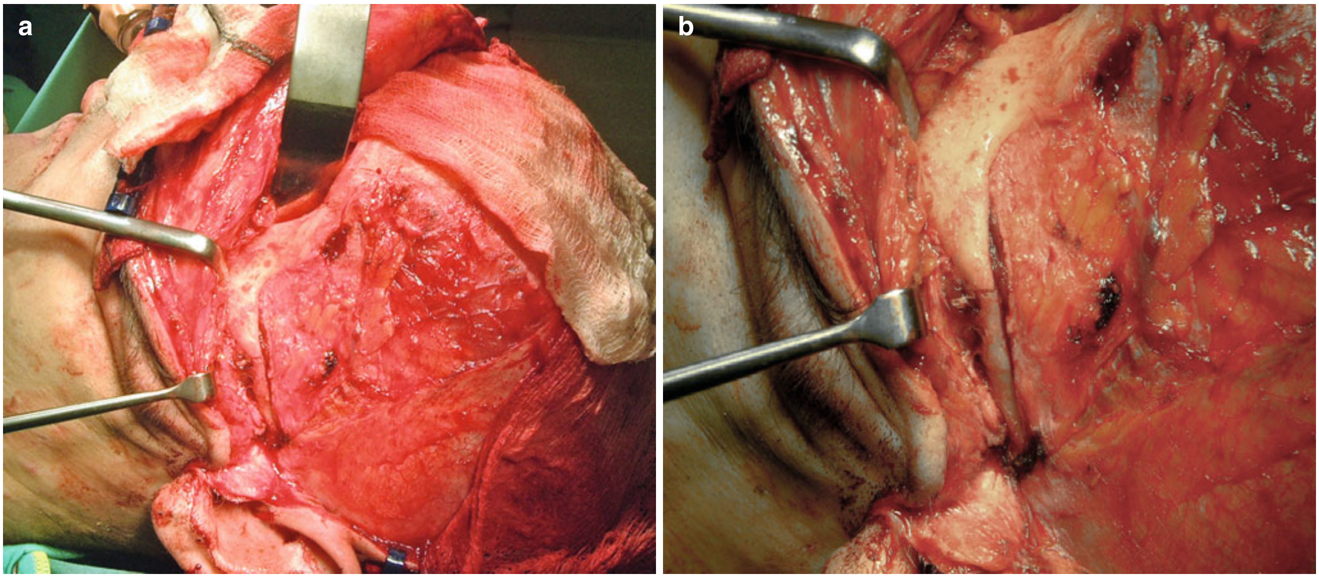

Fig. 8.142 Through a coronal flap, the entire arch/frontal process complex can be exposed (**a**, **b**)

Fig. 8.143 The FZ suture can be repaired using a more posterior positioned plate. This has the advantage of being nonpalpable through the skin postoperatively. Unfortunately, if it ever needs to be removed, access will be difficult

In many cases, such injuries have overlying soft tissue lacerations. These tend to lay directly over the fractures and often provide excellent access (see Figs. 8.144 and 8.145).

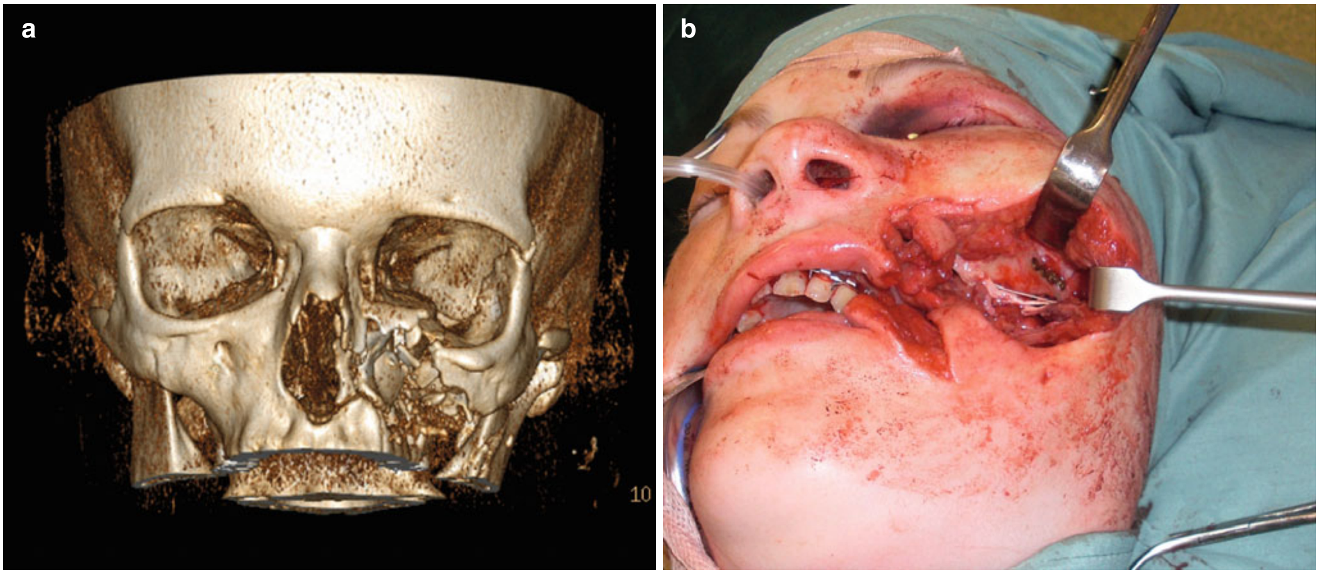

Fig. 8.144 This complex injury was repaired though the overlying laceration. This provided excellent access to most of the fracture (**a**, **b**)

Fig. 8.145 Postoperative film

8.9 Soft Tissue Resuspension

Failure to resuspend the soft tissues can result in sagging postoperatively and asymmetry of the face. Although the postoperative films may look good, the final result can be very disappointing. Careful resuspension should therefore be undertaken prior to wound closure. A number of techniques exist. Strong sutures may suffice. These engage the deeper tissues and need to be anchored superiorly. Alternatively, natural or synthetic materials may be used. Which is used is a matter of personal choice. In all cases, the aim is to support the tissues to prevent sagging when the patient is upright. If suspended correctly, the tissues should eventually reattach to the underlying bones (see Figs. 8.146, 8.147, 8.148and 8.149).

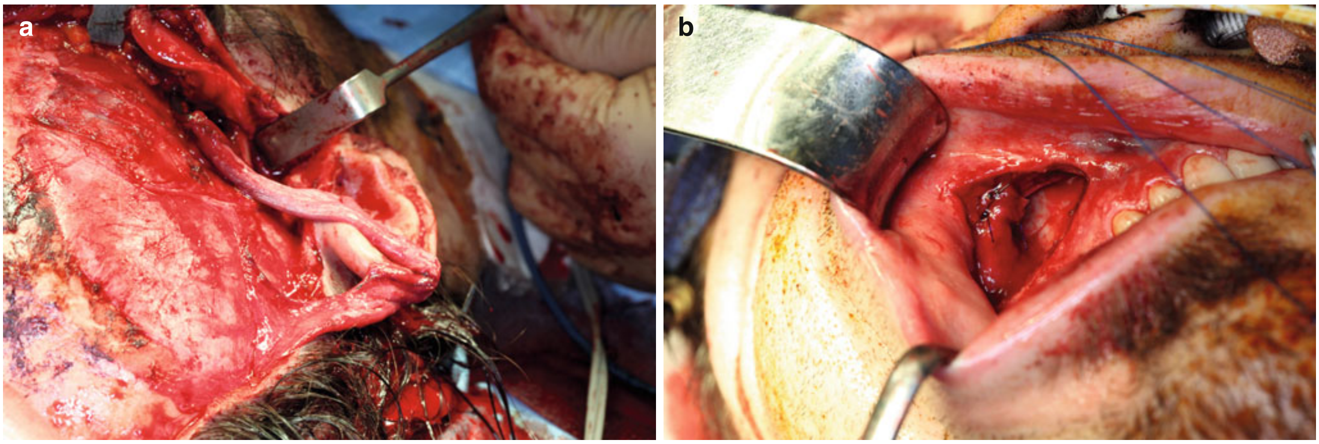

Fig. 8.146 Resuspension of the soft tissues using pericranium from a laterally based flap. This is secured to the deeper tissues at the buccal mandibular–retaining ligaments (**a**, **b**)

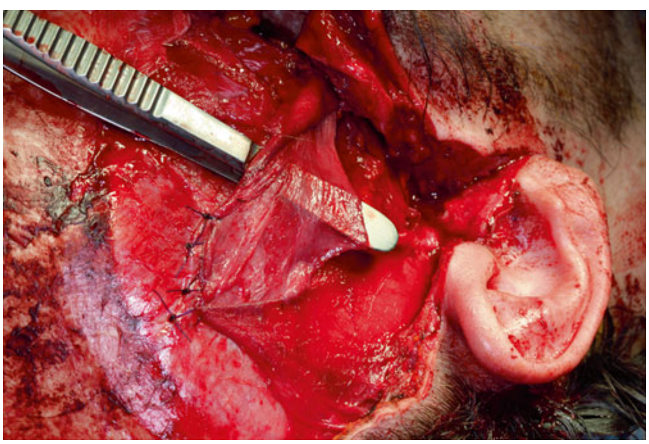

Fig. 8.147 The fascia is then secured to the temporalis fascia

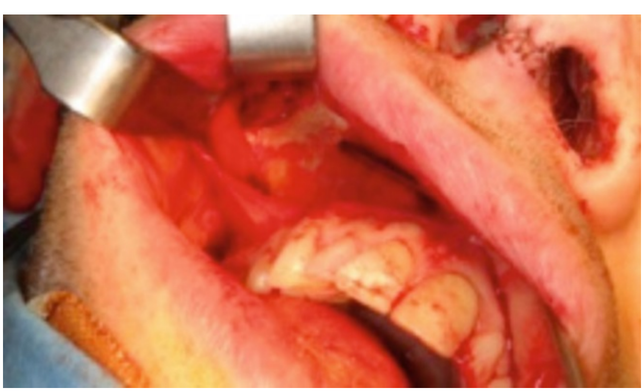

Fig. 8.148 Resuspension using "endotine" implant

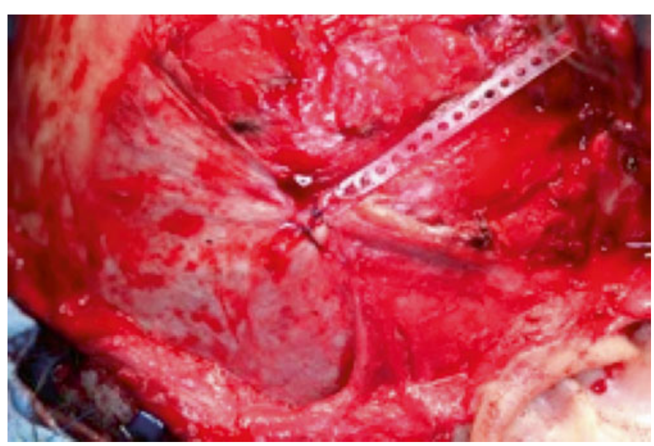

Fig. 8.149 Resuspension using "endotine" implant

8.10 Other Forms of Fixation

By and large, these are rarely required as the vast majority of fractures can be managed using varying combinations of the techniques just described. External fixation may occasionally have a small role to play. Alternatively the zygoma can be "kebabed" using a transantral K-wire. This is certainly quick, but is a blind procedure, with risks to both eyes if incorrectly performed.

Useful points to remember

If the eyelids are swollen, gently pressing on them (not the globe) for a few minutes reduces this sufficient to assess visual acuity.
Numbness of the cheek and upper lip is an important sign that should generate a high index of suspicion for orbital or cheek bone fracture.
Remember the nasolacrimal duct during infraorbital/eyelid access
Isolated arch or simple fractures that are incomplete at the FZ suture are those most suitable for closed reduction
Arch fractures with associated coronoid fractures are at risk of ankylosis
Correct alignment of the sphenozygomatic suture (lateral orbital wall) is a good on-table indication that the fracture is correctly reduced
A force duction test should be performed at the end of any reduction. As the fractures realign, orbital soft tissues may become trapped.
Beware late enophthalmos: follow-up patients closely
Place sticky tape over the repaired site. Don't draw on the patient—they may try to rub it off!
Not all vision-threatening proptoses are caused by retrobulbar hematoma

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Orbital Fractures

9

Simon Holmes, Michael Perry, Joe McQuillan, and Steve White

9.1 Applied Anatomy

> All "black eyes" associated with numbness of the cheek and upper lip, should be assessed carefully—the patient may have an isolated fracture of the orbital floor, or a fracture of the zygomatic complex (*see* Fig. 9.1). Nasoethmoid, midface and skull fractures may also involve the orbit.

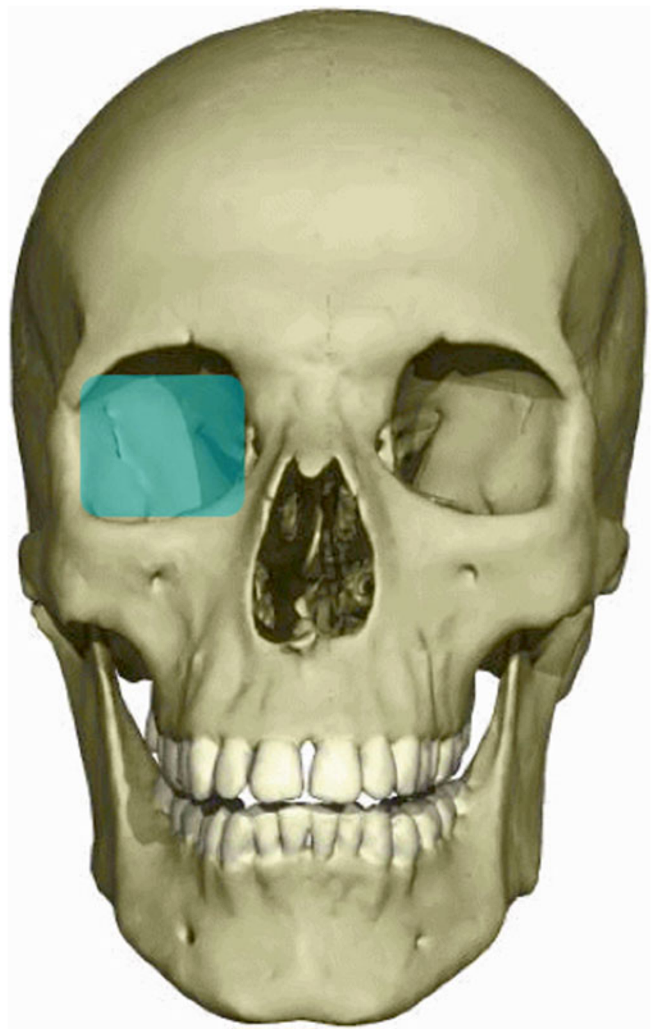

Fig. 9.1 Orbital fractures commonly involve the floor and/or medial wall but it is important not to forget the two remaining walls in your assessment

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The orbit is a roughly pyramidal-shaped structure. Each has a volume of approximately 30 mL. Both orbits are aligned in such a way that their medial walls are almost parallel to each other, while their lateral walls form lines that intersect each other at approximately 90° (*see* Fig. 9.2).

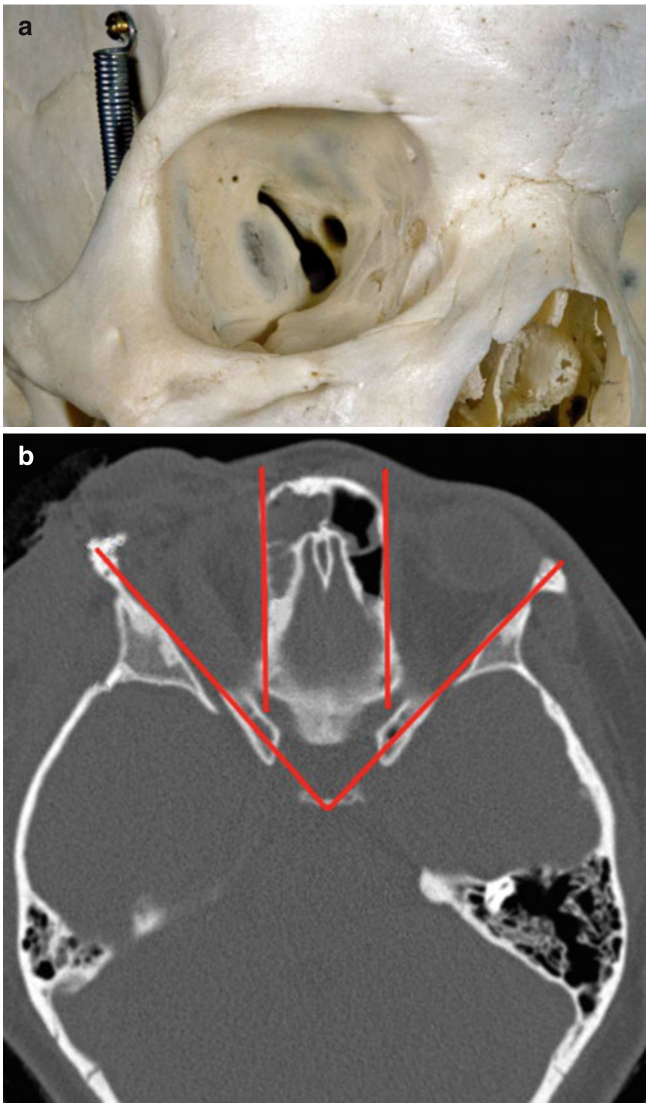


Fig. 9.2 A good understanding of orbital topography is essential to the management of orbital, zygomatic, and nasoethmoid trauma. Precise reconstruction of orbital wall geometry is required to reestablish the correct orbital volume. Failure to repair injuries adequately can result in considerable morbidity and enophthalmos (**a**, **b**)

The shape and structure of the orbital floor is complex and familiarity with its geometry is essential to understanding the treatment of orbital fractures. The four orbital walls are composed of a number of different bones that vary significantly in thickness and strength (*see* Fig. 9.3). The orbital floor and medial orbital wall are particularly delicate and prone to injury, either in isolation (blowout fractures), or in combination with the adjacent supporting bones (zygomaticomaxillary/nasoethmoid fractures). Fractures of the lateral wall are usually seen with fractures of the zygoma. Fractures of the orbital roof should be regarded as skull base fractures. These rarely occur in isolation.

The floor of the orbit inclines upwards at approximately 30° as it passes from anterior to posterior and at approximately 45° from lateral to medial. Towards the back of the orbit, the junction between the floor and medial wall becomes less obvious as the two converge to form the "posteromedial bulge" (*see* Fig. 9.4). This is an area of particular importance in the repair of orbital fractures. The medial wall is a very delicate structure, being composed of the ethmoid bones, deep to which lay the ethmoidal air cells. The ethmoidal blood vessels pass through the orbit and into the nose. These

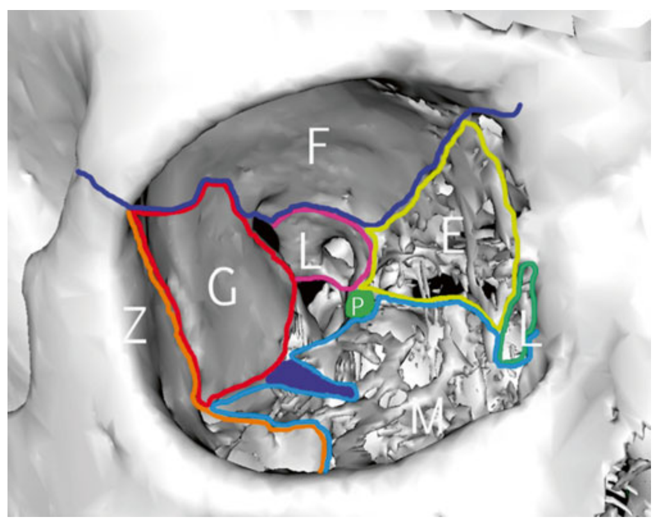


Fig. 9.3 The orbit is made up from a number of different bones, all of varying thickness. *E* ethmoid, *F* frontal, *G* greater wing of sphenoid, *L*(*post*) lesser wing of sphenoid, *L*(*ant*) anterior wing of sphenoid, *M* maxilla, *Z* zygoma. The floor and medial wall are especially thin and most commonly fractured in trauma

are important landmarks during dissection and may bleed profusely following trauma.

The infraorbital nerve passes forward along the orbital floor, supplying sensation to most of the cheek and ipsilateral half of the nose and upper lip. Sometimes it passes within a bony tunnel, other times it lays in a shallow groove directly in contact with the orbital periosteum. This can make dissection along the orbital floor a bit tricky (*see* Fig. 9.5).

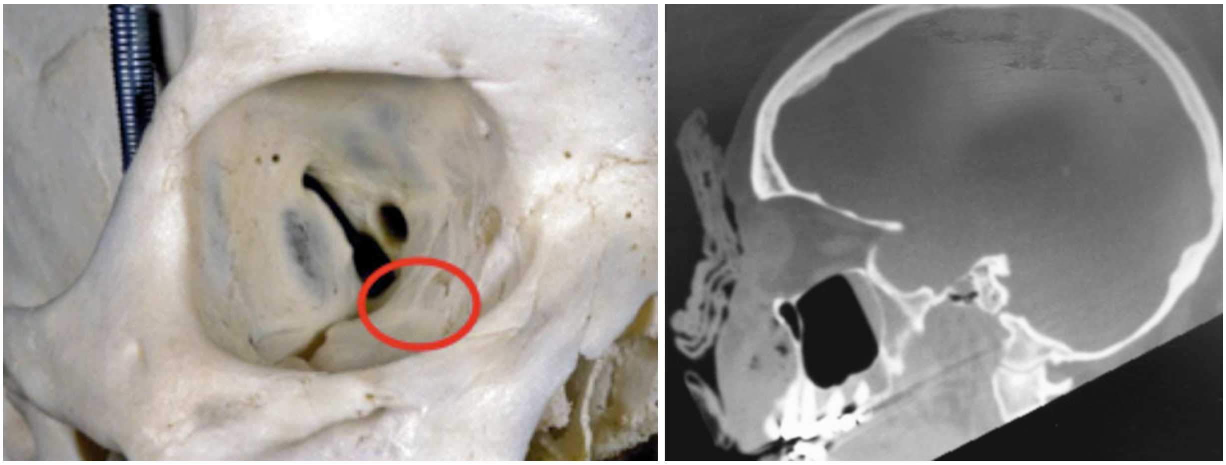


Fig. 9.4 The "posteromedial" bulge is a key site in repair (**a**, **b**). Familiarity with the curvatures of the floor and medial wall is essential. The floor is not flat, but as seen has a number of gentle curves. This has important implications in the choice of material used in the repair of large defects

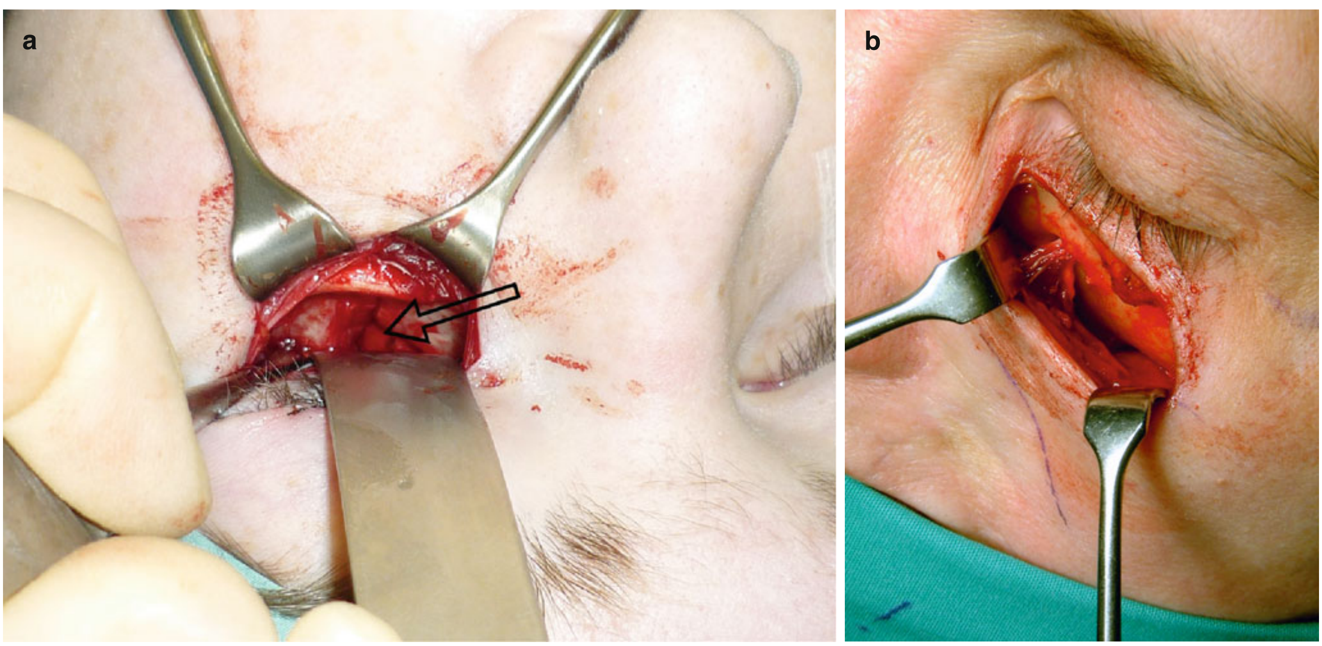


Fig. 9.5 The infraorbital nerve is commonly injured during trauma, but is also at risk of injury during orbital dissection. While its position along the floor of the orbit is generally predictable, its depth can vary. It may be covered entirely by a thin sheet of bone, or it can be in direct contact with the periosteum (usually the latter). *Black arrow* shows the orbital floor fracture

Coordinated movements of the eye are achieved by the extraocular muscles: four recti and two oblique. These are very delicate structures. The four recti muscles arise from the tendinous ring—a fibrous band that passes around the orbital apex. As the muscles pass forward they form a muscular "cone" before inserting into the sclera of the globe. Each orbit therefore has an "extraconal" and "intraconal" compartment. These communicate with each other between the edges of the recti muscles.

Orbital fat makes up the bulk of the retrobulbar contents. Within this pass the neurovascular structures of the eye and the extraocular muscles. Fat within the cone is termed "intraconal;" that surrounding the muscles is termed "extraconal." Throughout the fat, fine but strong fibrous septa form a complex interlacing pattern of numerous, tiny fat-filled compartments. This delicate "bubble-wrap" type arrangement provides structural support for the globe and allows its free movement. In a sense, retrobulbar fat acts like a bursa (cf the buccal fat pad), facilitating movement and providing support. Damage to the orbit can result in herniation of the fat and trapping of the septa. This can restrict eye movements, resulting in diplopia.

The trochlea is a cartilaginous ring that supports the superior oblique muscle. It is attached to the periorbita within the fovea trochlearis, along the superior-medial orbit. Dissection in this area must be undertaken with particular care (usually when raising a coronal flap).

> Fractures involving the orbit often result in the classic "black eye," as blood is contained by the orbital septum. However not all black eyes are due to blowout fractures. Fractures to the nose, skull base and zygoma also extend into the orbit and therefore can develop similar clinical signs (*see* Fig. 9.6).

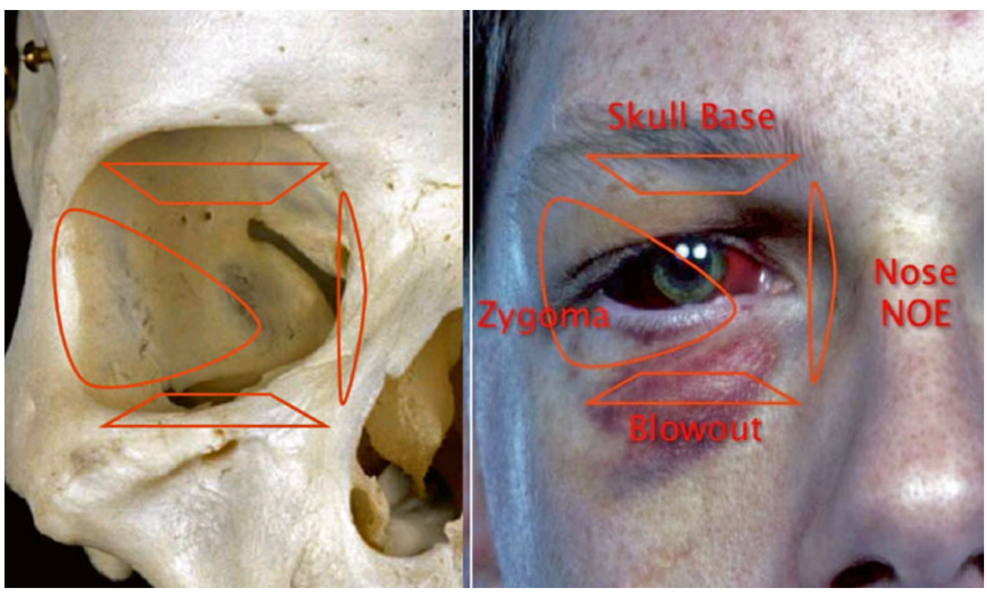


Fig. 9.6 While the well-defined "black eye" usually means there is a fracture of the orbit, this gives no indication of the site or the extent of injury (**a**, **b**)

9.2 Blowout Fractures

The term “blowout fracture” refers to an isolated defect in one of the orbital walls, most commonly the floor or medial wall. Displacement of the bone can vary from minimal (not requiring repair), to significant, requiring reconstruction. The orbital rims and surrounding bones of the face remain intact.

The classically taught mechanism of injury for a “blowout” fracture is that following a direct blow to the globe (e.g., from a squash ball). The globe transmits the energy posteriorly, increasing the pressure within the bony orbit, which then “gives” at its weakest spot. This is usually the floor or medial wall. However, blowout fractures may also occur following a blow to the prominence of the cheek. In this mechanism the bone “buckles,” resulting in deformation and fracture propagation along the weakest lines. Bone is a “plastic” material and therefore it tends to bend or deform before it breaks (especially in children). Hence the zygoma itself may not fracture.

Most blowout fractures occur along the thin floor of the orbit. This is weakened further by the presence of the infraorbital canal. Herniation of orbital contents (usually extraconal fat) then occurs into the maxillary sinus. Less commonly, blowout fractures can occur along the medial wall. Isolated blowout fractures of the orbital roof or lateral wall are considerably rarer. Fractures at these sites tend to be associated with other fractures in the surrounding bones.

Depending on the size of the defect and whether there is any entrapment of the orbital contents, blowout fractures can result in one or two clinical problems.

1. Diplopia (from entrapment of soft tissues). Usually extraconal fat becomes trapped within the fracture. As the patient tries to move the globe (usually to look upwards) the tethered fat prevents the inferior rectus muscle from freely moving. Sometimes the muscle itself can become trapped in the fracture. This is a more serious problem, as direct injury to the muscle can result in scarring and persistent diplopia (*see* Fig. 9.7).
2. Enophthalmos. This is a “sunken-in” appearance of the globe. This may not be apparent when the patient is first seen, due to the compensatory effects of swelling within the orbit. Hence patients need to be followed up for a short while. Enophthalmos is a “volume problem,” in that the volume of the orbit has expanded following displacement of the wall, allowing the contents to sink back (*see* Fig. 9.23).

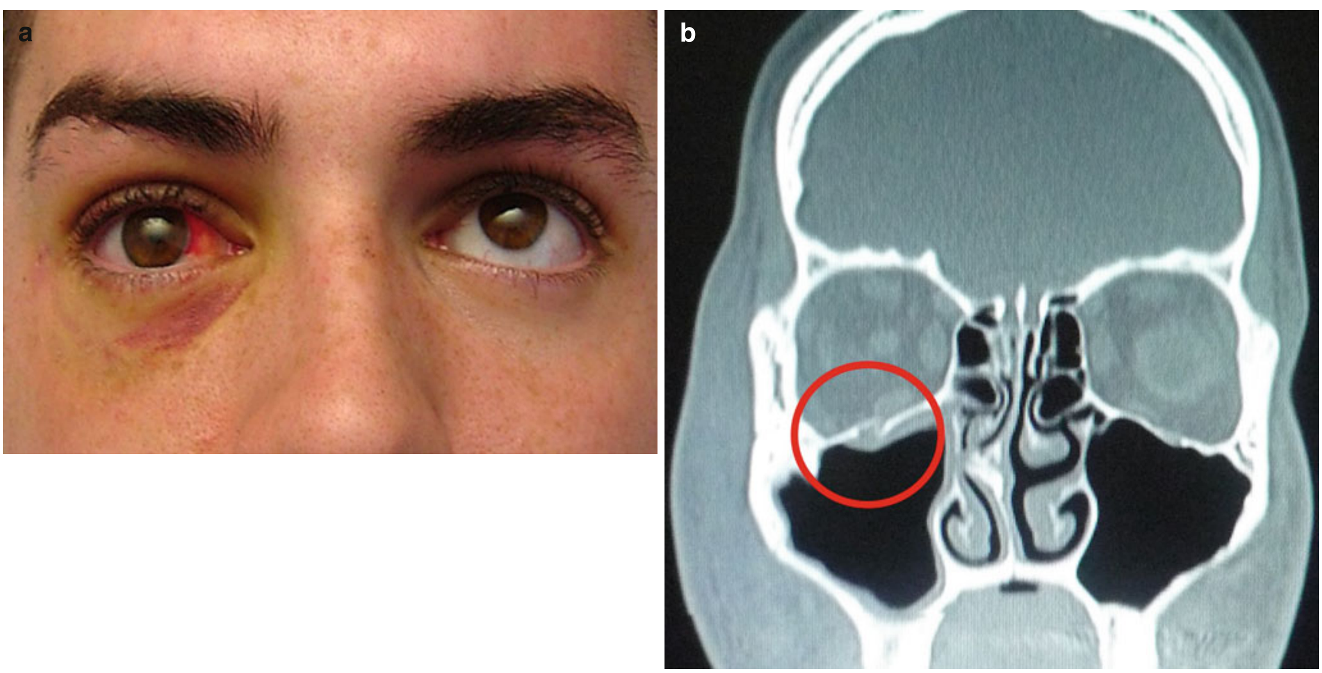


Fig. 9.7 Blowout fracture of the right orbital floor (*red circle*) (**a**, **b**). There is mechanical restriction of upward gaze due to trapping of the extraconal fat at the fracture. This needs to be released

9.3 Clinical Assessment

This is summarised in Tables 9.1 and 9.2. Preliminary assessment of the eye always takes priority over the fracture itself. With localised injuries, a dilated pupil is most likely to be due to traumatic mydriasis, but always keep in mind the possibility of a coexisting head injury or serious ocular injury. Not all serious globe injuries are immediately obvious. Sometimes there is considerable swelling of the eyelids, making examination of the eye difficult. In such cases, gently pressing on the eyelids (not the globe) for a few minutes can reduce this, although epiphora can make the eyelids somewhat slippery. Ideally a pair of Desmarres or Jaffe lid retractors should be used. These can safely open the lids without putting pressure on the globe (*see* Fig. 9.8).

If you are really struggling, a pair of clean, bent paperclips do surprisingly well as makeshift Jaffe-like retractors. Although far from ideal, these can often open even the most swollen of lids, at least sufficiently to assess visual acuity, pupillary size and reaction, and to visualise the anterior chamber for hyphema. If a penetrating injury to the eye is suspected from the history, pressure should be avoided (*see* Fig. 9.9).

Table 9.1 Initial assessment of isolated orbital injury

Visual acuity
Pupil size and reaction
Periorbital bruising/eyelid injuries
Subconjunctival haemorrhage
Numb cheek
Restricted eye movements (usually upwards) with diplopia
Retraction sign and forced duction test
Enophthalmos (although this can be masked by swelling)
Consider also the following: Nasolacrimal dysfunction Presence of foreign bodies Globe rupture
Contact lenses and superficial foreign bodies should be removed

Table 9.2 Investigations

Plain radiographs Occipitomental (OM). Look for the "hanging drop" sign. This represents the herniation of orbital contents into the maxillary sinus. A fluid level in the sinus suggests a fracture nearby
Coronal/axial CT of orbits
Orthoptic assessment (*see* text for discussion)
Measurement of exophthalmos/enophthalmos

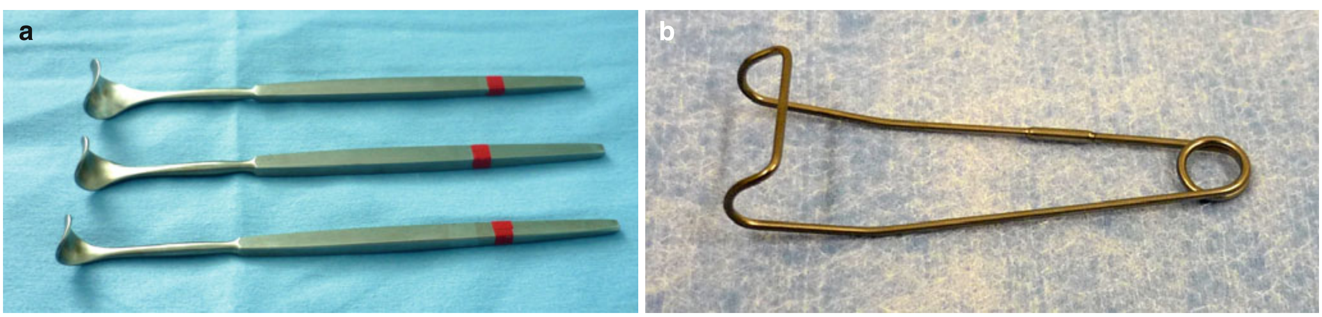


Fig. 9.8 Desmarres and Jaffe lid retractors (**a**, **b**)

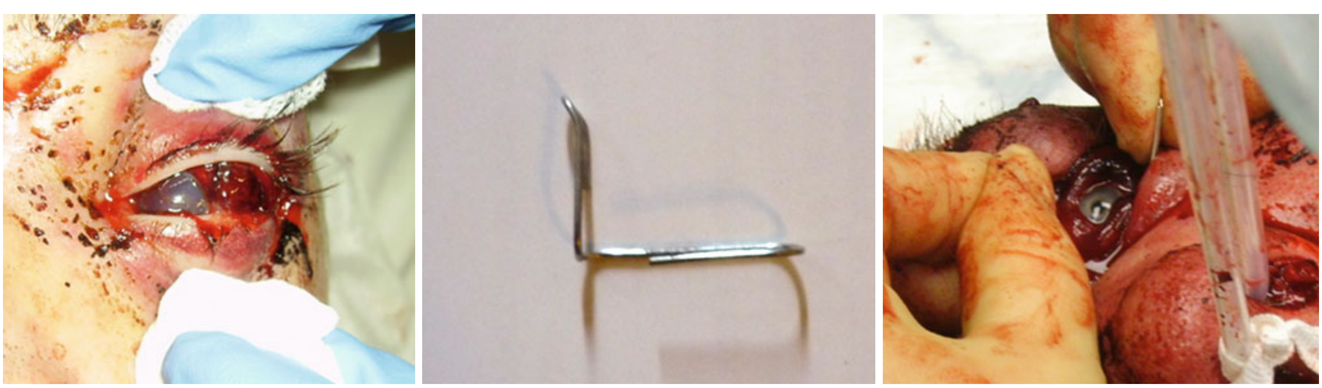


Fig. 9.9 Opening swollen eyelids can be very difficult. Sometimes gentle but sustained pressure on the lids can reduce swelling (note there is no pressure being exerted on the globe). If the correct retractors are not available and examination cannot wait, a couple of bent paperclips can act as makeshift retractors (make sure they are cleaned first) (**a**–**c**)

A significant number of injuries to the bony orbit are associated with injuries to the globe itself. Always check the visual acuity and seek ophthalmic advice if you are not sure. If a penetrating injury to the eye is suspected from the history, pressure should be avoided (*see* Fig. 9.10).

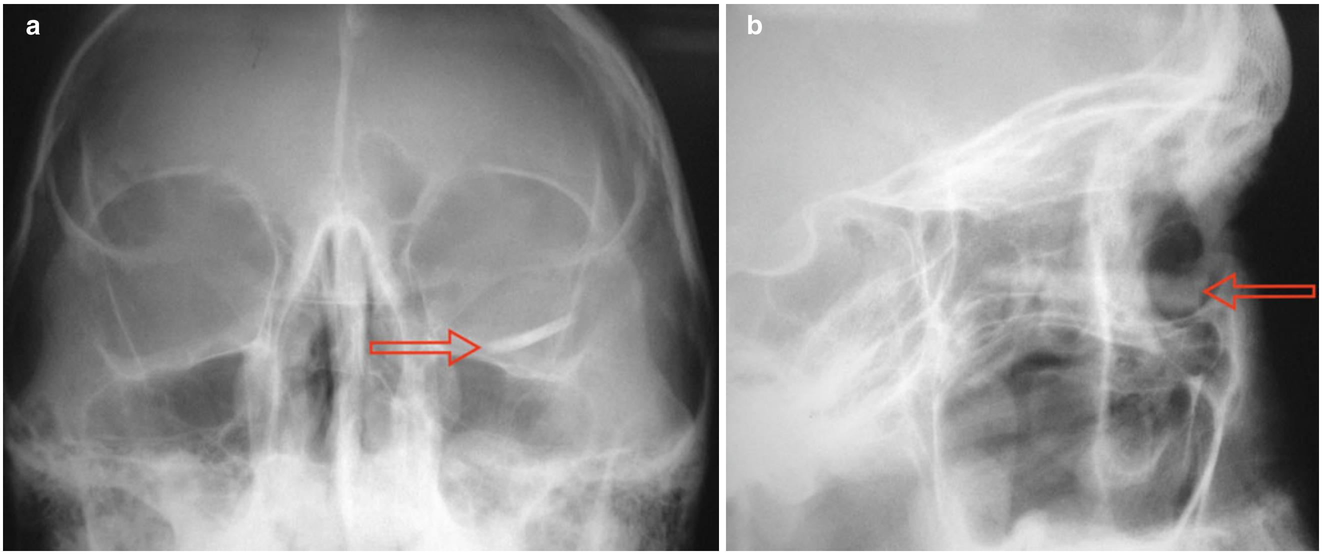


Fig. 9.10 A large shard of glass can be seen in a patient who was hit in the face with a beer glass (**a**, **b**). Surprisingly he did not sustain any serious injuries to the globe. Careful evaluation of the globe is essential before this is retrieved. *Red arrow* shows shows glass foreign body

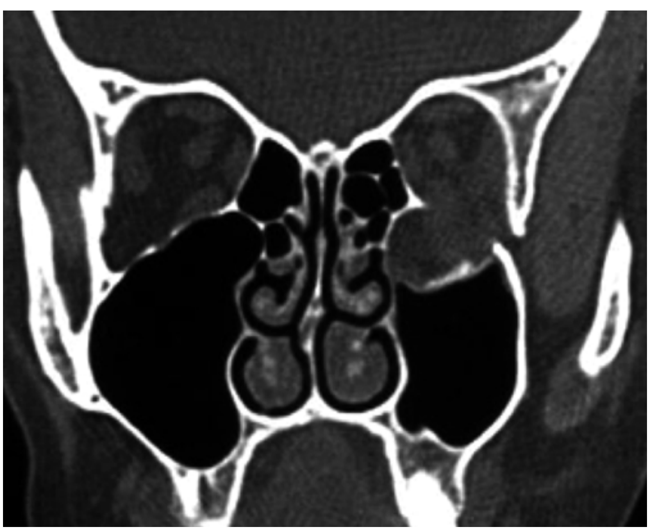


Fig. 9.11 CT confirmation of an extensive fracture to the left orbital floor. This involves the posteromedial bulge

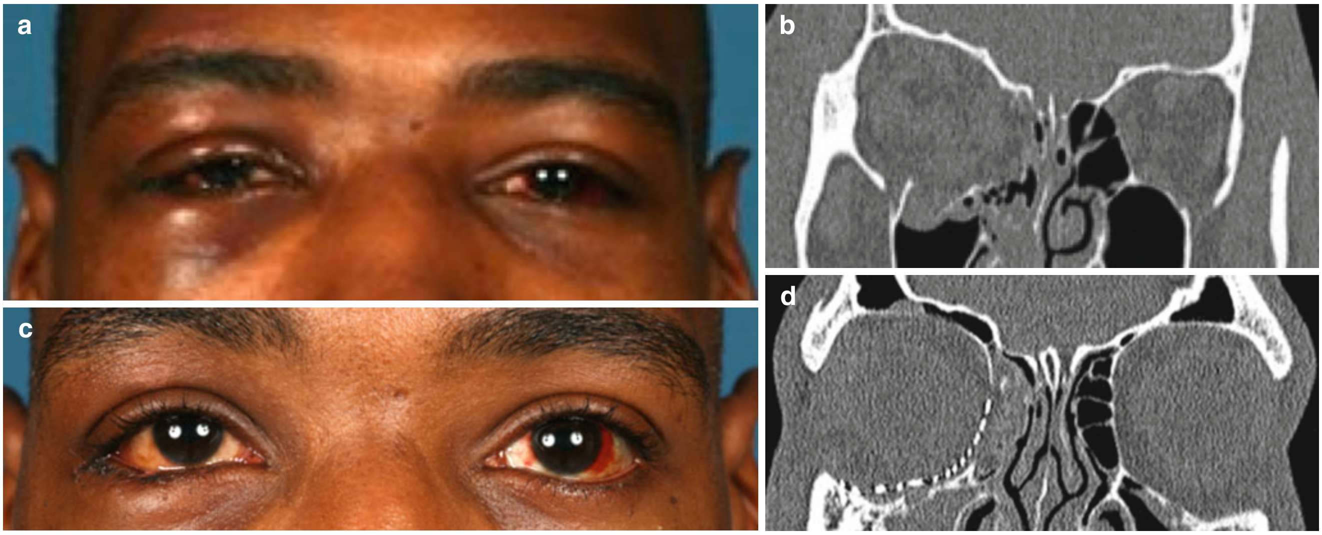


Fig. 9.12 CT evaluation is now commonly undertaken for both pre- and postoperative assessment of the orbit following trauma (**a**–**d**). Such a large two-wall defect as shown is a very difficult fracture to precisely repair. Postoperative clinical examination will give no indication of long-term outcomes, but a CT showing a correctly positioned plate is certainly reassuring. If the plate is incorrectly placed, the patient may need to return to theatre

9.3.1 The Role of the Orthoptist

Orthoptists are specialists in ocular motility and paediatric visual development. Their input into the management of orbital fractures is valuable both pre- and postoperatively. The extraocular muscles are particularly susceptible to damage following orbital trauma, especially when fractures have occurred. Any damage to these muscles (or the cranial nerves that innervate them) has an impact on the "laws of eye movements" and subsequently the patient's ability to keep their eyes working in a coordinated fashion.

> Limitation of eye movement following trauma has several varied causes and therefore does not always require surgery. Similarly, diplopia following repair does not automatically mean that surgery was performed inadequately—although it can. Orthoptic input in both these scenarios is therefore essential to help determine which cases require exploration and which cases require nonsurgical management.

9.3.1.1 The Orthoptic Assessment

It is important to take into account the amount of periorbital oedema when referring a patient. If the eye cannot open, or can only marginally open, a full ocular movement assessment will not be possible. Therefore assessment needs to be delayed to allow the swelling to sufficiently settle. A full orthoptic assessment involves several different tests to assess the patient's vision, binocularity, ocular movements, and symptoms.

9.3.1.2 Visual Acuity (Vision)

In ophthalmology, visual acuity is one of the most important measurements to make because it is generally the best measurable indication of outcome. However, this is not the case with orbital fractures, which usually result in mechanical-type problems (restriction of movement or volume effects). Nevertheless, it is still an important monitoring tool. It is also especially important to identify any significant ocular injury before surgery is undertaken. Some globe injuries may contraindicate exploration of the orbit.

9.3.1.3 Cover Test

The cover test is a quick and accurate assessment of the positioning and balance of the patient's eyes in the primary position. It quickly assesses the presence and size of any strabismus (squint), which can be pre-existing (often congenital), or secondary to the trauma.

9.3.1.4 Binocular Functions

Binocular vision is when both eyes are used simultaneously to interpret one image. There are three levels of this: simultaneous perception, sensory/motor fusion, and stereopsis.

1. Simultaneous perception is the ability for a person to perceive simultaneously two images, one formed on each retina.

2. Sensory fusion: the ability for a person to perceive two similar images, one from each eye, and interpret them as one.
3. Motor fusion is the ability for a person to maintain sensory fusion through a range of ocular movements, or vergences (e.g., convergence and divergence).
4. Stereopsis is the ability for a person to perceive the relative depth of an object based on binocular disparity.

9.3.1.5 Ocular Movements

There are four groups of ocular movements: smooth pursuits, saccades, optokinetic nystagmus (OKN), and vergences.

1. Smooth pursuits: this is a method to assess the function of all six pairs of extraocular muscles. It is tested by having the patient move their eyes into the nine cardinal positions to isolate different muscles and assess the balance of each with its yoke muscle. (Yoke muscles are contralaterally paired extraocular muscles that work together to direct the gaze in a given direction. For example, in directing the gaze to the right, the right lateral rectus and left medial rectus operate together as yoke muscles). It is important to be able to differentiate between a restriction of ocular movements and an underaction. An underaction will have a neurogenic cause whereby a restriction will be mechanical.
2. Saccades: this is a basic rapid eye movement system, which allows rapid, accurate changes in fixation.
3. Optokinetic nystagmus: this is a refixation movement, most commonly noted when somebody is looking out of the window of a moving train.
4. Vergences: Convergence is the ability for the eyes to move towards each other in conjunction with each other. Divergence is the ability for the eyes to move apart from each other.

9.3.2 Laws of Eye Movements

There are certain laws that govern how the eyes move:

1. Herring's law of equal innervation: a muscle and its yoke muscle (contralateral synergist) receive equal and simultaneous innervation to contract so the eyes move as a pair.
2. Sherrington's law of reciprocal innervation: when a muscle receives an impulse to contract, an equal inhibitory impulse is sent to its antagonist partner to relax.
3. Muscle sequelae: when underaction of a primary muscle occurs, the following sequelae develop:
   - The primary affected muscle's yoke muscle overacts
   - The direct antagonist of the affected muscle contracts to overact
   - The antagonist of the Yoke muscle underacts

The extent of muscle sequelae that can develop varies among people.

9.3.3 Extraocular Muscles

The six extraocular muscles are innervated by three cranial nerves: the oculomotor nerve (IIIrd), the trochlear nerve (IVth) and the abducens nerve (VIth).

IIIrd nerve innervates

- Superior rectus: elevation (max in abduction), intorsion, and adduction
- Inferior rectus: depression (max in abduction), extortion, and adduction
- Medial rectus: adduction
- Inferior oblique: elevation (max in adduction), extortion, and abduction
  - Levator palpebrae superioris
  - Sphincter pupillary muscle

IVth nerve innervates

- Superior oblique: depression (max in adduction), intorsion, and abduction

VIth nerve innervates

- Lateral rectus: abduction

9.3.4 Hess Charts

The Hess chart is one part of the orthoptic assessment and is very useful for monitoring ocular motility. These charts are used in the investigation of entrapment and strabismus. By dissociating the eyes with a mirror (using the Lees screen) it is possible to locate the position of the nonfixing eye when the other eye is fixed on specific points on the screen. Each inner point on the screen represents 15° from the central point and each outer point 30°. A field is plotted for each eye (*see* Figs. 9.13 and 9.14).

When interpreting Hess charts and comparing the right and left fields, the smaller field represents the affected eye. Any difference in sizes indicates "incomitance" and recent onset of a problem. Similar sizes represent concomitance and therefore a more long-standing problem.

When looking at the smaller field you need to look at:

- The deviation in the primary position
- The greatest inward displacement. This indicates the primary underacting and affected muscle.
  - Any outward displacement. This indicates an overacting muscle.

There are three types of orbital floor blowout fractures, which can be differentiated based on whether the ocular motility defect is mechanical and/or neurogenic.

Fig. 9.13 Lees screen

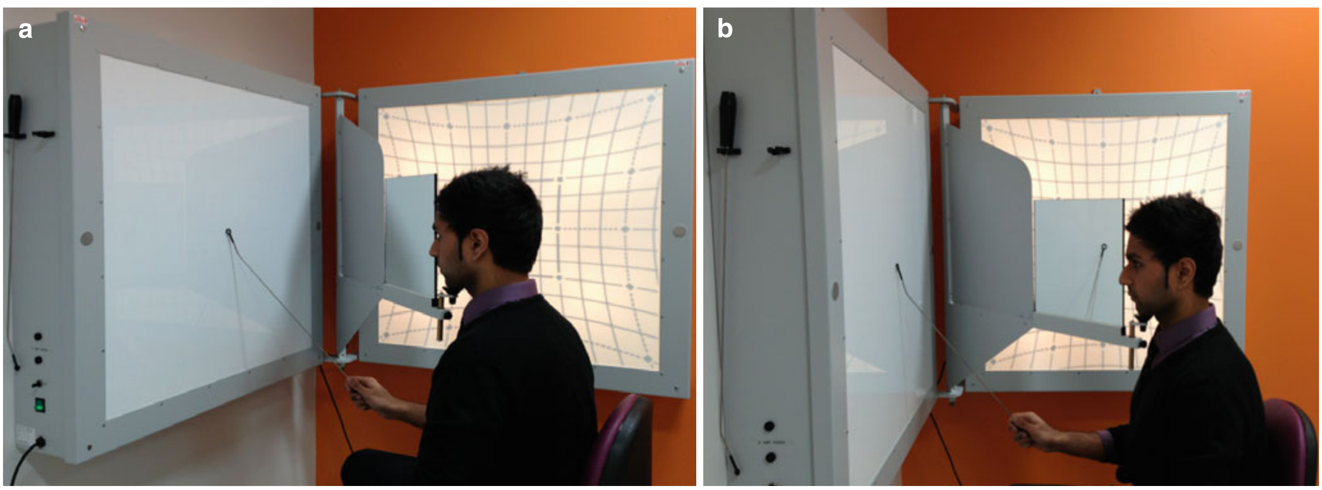


Fig. 9.14 Example of a patient performing a Hess charting with the Lees screen (**a**, **b**)

9.3.4.1 Type 1

This is characterised by limited elevation of the affected eye due to a mechanical restriction. This can be associated with a "chin elevation head posture" to maintain a useful field of binocular single vision (BSV) (*see* Fig. 9.15).

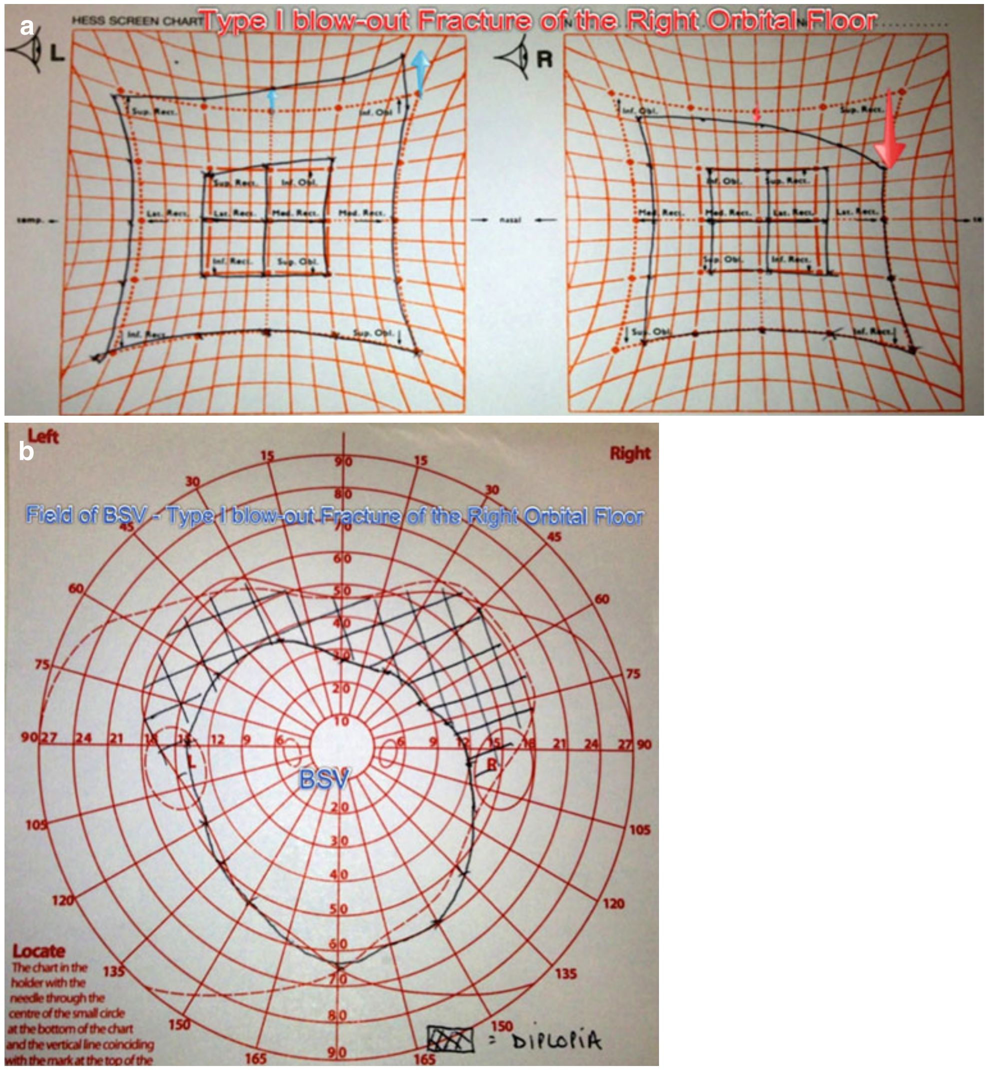


Fig. 9.15 (**a**) Looking at the Hess chart of the right field, you can see the limited elevation mainly affecting abducted elevation (*red arrows*). This also demonstrates Herring's law by the overaction of the contralateral synergist (*blue arrows*). Forced duction test is positive with the greatest limitation in abducted elevation. (**b**) Patients often adapt well to a reduced field of BSV as the defect is in the superior field, which is not as commonly used as the primary position and down gaze (*e.g.*, reading)

9.3.4.2 Type II

This is characterised by limited depression of the affected eye due to an inferior rectus palsy. The palsy occurs due to either damage to its nerve supply (oculomotor) or direct injury to the muscle (*see* Figs. 9.16 and 9.17).

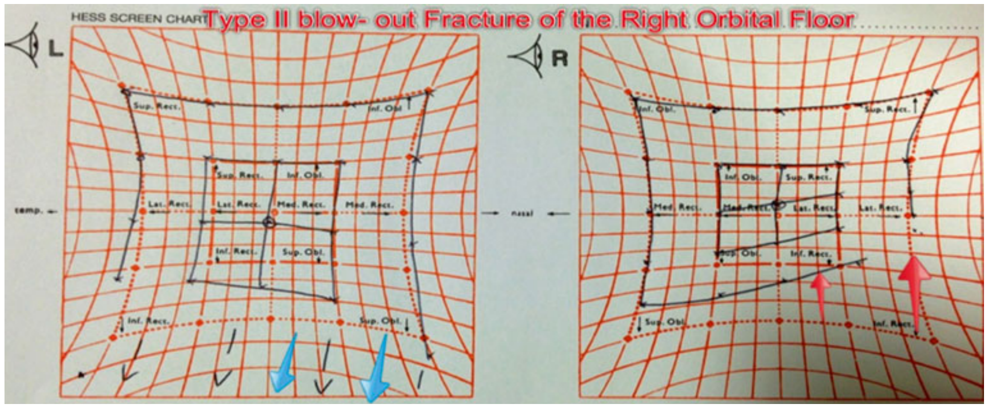


Fig. 9.16 The forced duction test is negative for mechanical restriction. Limited function of the inferior rectus commonly occurs and can last up to a year postinjury. *Blue arrows* indicate increased movements of the left eye. *Red arrows* indicate decreased movements of the right eye

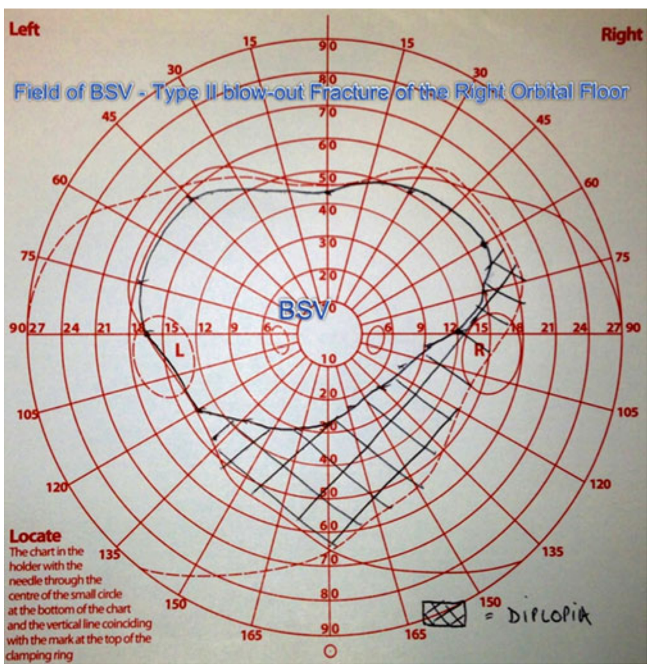


Fig. 9.17 Looking at the field of BSV, you can see these patients will often suffer with diplopia that is much more troublesome than in type I fractures. It affects downgaze, thus having an impact on walking, sports, reading, etc.

9.3.4.3 Type III

This is characterised by limited elevation and depression due to mechanical restriction and inferior rectus palsy respectively (*see* Figs. 9.18 and 9.19).

As with type II fractures, the loss of binocularity in down gaze is the biggest problem for the patient. If this recovers before the upgaze problems they are usually happy.

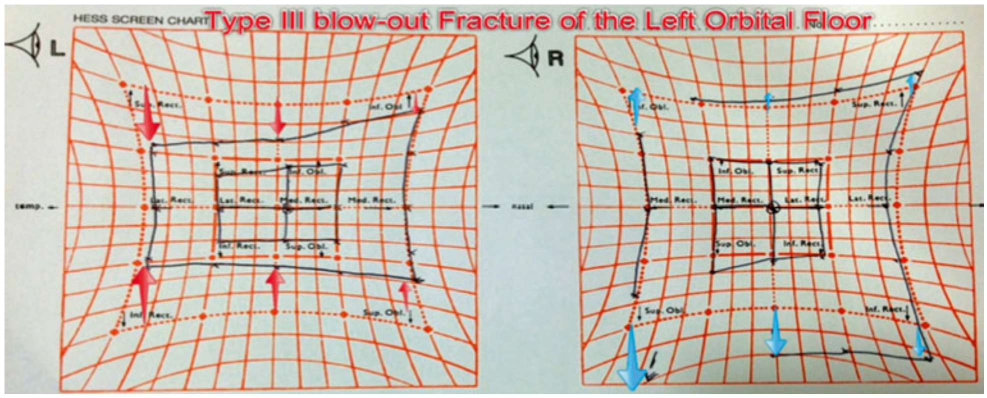


Fig. 9.18 Type III. This is a combination of types I and II, so you have a positive forced duction test mainly in abducted elevation. *Red arrows* indicate reduced movements of the left eye. *Blue arrows* indicate increased movements of the right eye

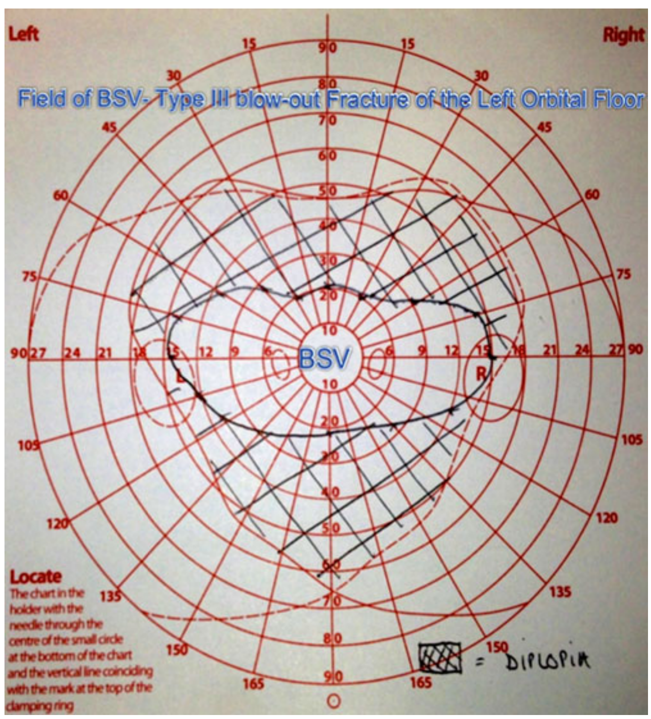


Fig. 9.19 Looking at the field of BSV, you can see these patients are left with a central, often elliptical area

9.3.4.4 Medial Wall Blowout Fractures

The medial wall of the orbit is more commonly fractured in association with the orbital floor than in isolation. Isolated medial wall fractures tend to have less of an effect on ocular motility than orbital floor fractures. Surgical repair usually results in significant improvements in ocular movements (*see* Figs. 9.20 and 9.21).

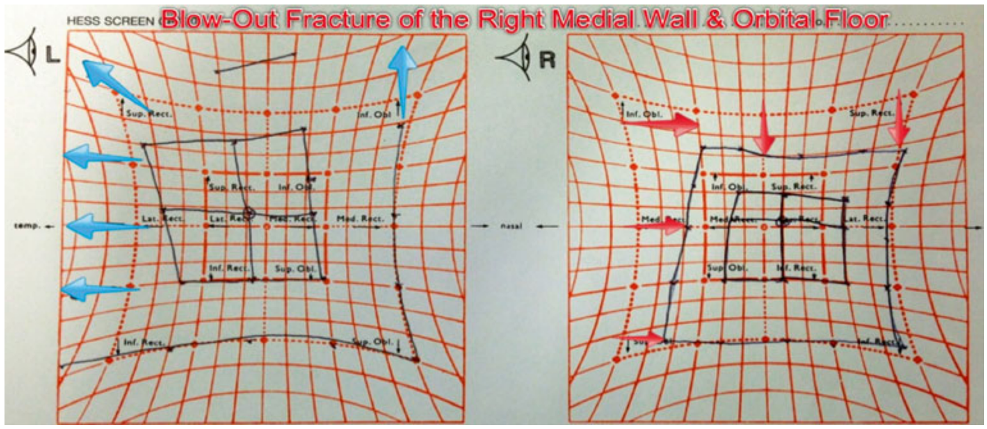


Fig. 9.20 This Hess chart demonstrates the restrictions of adduction and elevation found in a typical medial wall fracture combined with an orbital floor fracture. *Blue arrows* show the increased movements of the left eye. *Red arrows* show the reduced movement of the right eye

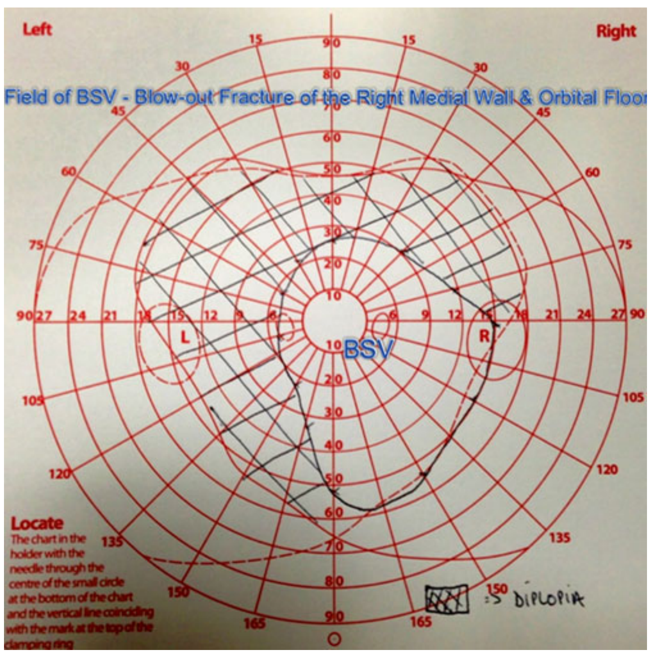


Fig. 9.21 The field of BSV shows the significant area of diplopia and the reduced and eccentric area of binocular single vision. Patients will often adopt abnormal head postures (face turns and tilts) to try to centralise this area

9.3.5 Measuring Globe Position

The horizontal position of the globe can be measured using an exophthalmometer. This gives a numerical value of its position in the anteroposterior direction. Exophthalmometry helps verify and determine the extent of any enophthalmos. It also helps evaluate the effectiveness of any repair (*see* Figs. 9.22, 9.23, 9.24 and 9.25 and Table 9.3).

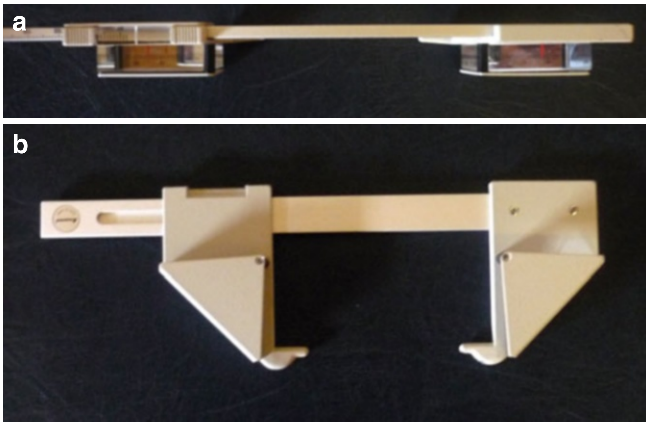


Fig. 9.22 Hertel exophthalmometer (**a**, **b**)

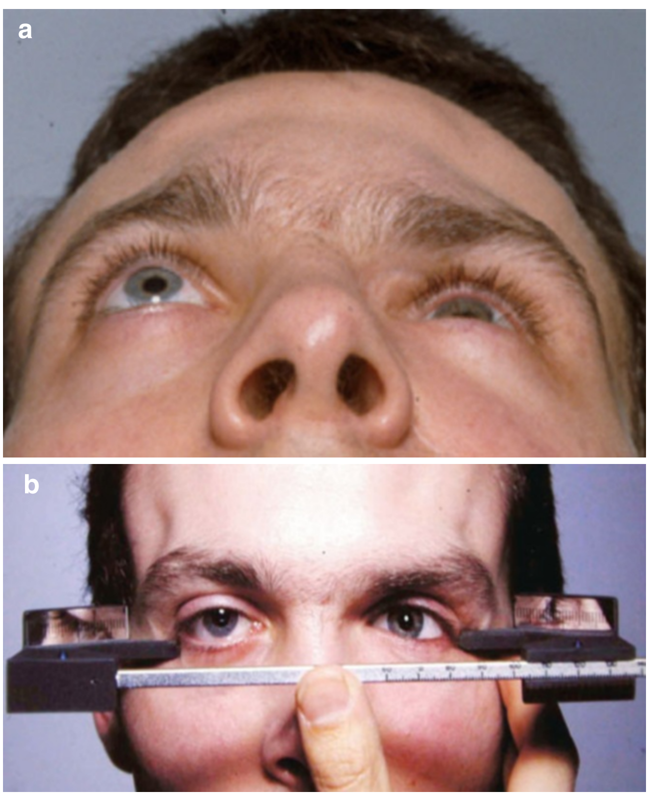


Fig. 9.23 Correct positioning is important. Measurement will be difficult if there is coexisting displacement of the zygoma (**a**, **b**)

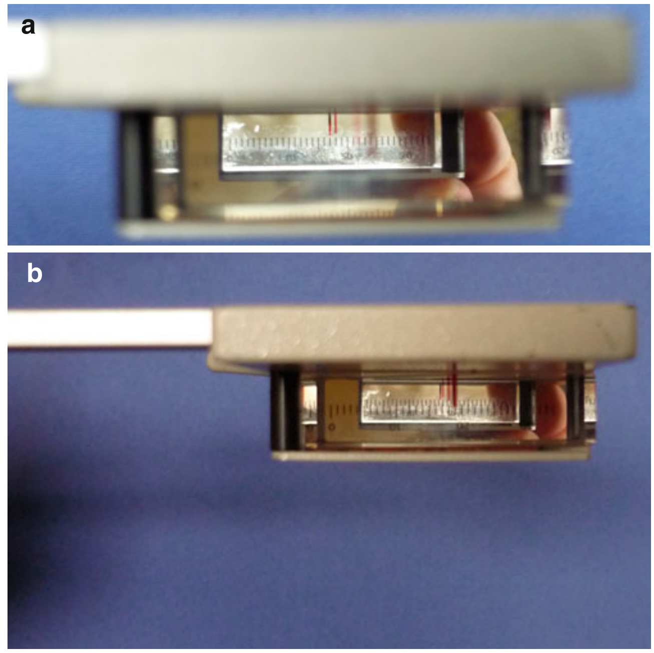


Fig. 9.24 The mirrors are used to take the measurements (**a**, **b**)

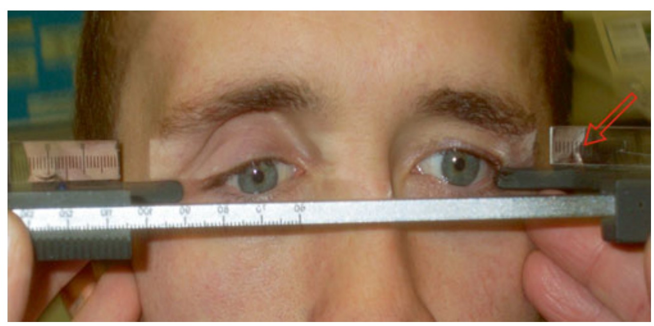


Fig. 9.25 Each cornea is viewed in its corresponding mirror and measured against the graduated marks. *Red arrow* shows the reflection of the cornea against the scale

Table 9.3 How to use a Hertel exophthalmometer

1. Position yourself opposite the patient at the same eye height
2. Make sure the patient is looking straight at the bridge of your nose
3. Position the feet of the exophthalmometer accurately at the patient's outer canthae with gentle pressure backwards so that the feet are resting on the orbital rim
4. Align the parallax eliminating mark on the exophthalmometer appropriately
5. Read off the position of the anterior most cornea on the scale
6. When recording the findings, make sure you record the intercanthal distance as well as the exophthalmometry reading to allow future comparisons

9.4 Management of Orbital Fractures

Whenever an injury to the globe or its associated structures is suspected, an ophthalmic opinion should always be sought. Initial management is similar to patients with fractures of the zygomaticomaxillary complex and is detailed in that chapter.

Patients should be advised not to blow their nose. The concern here is not the surgical emphysema per se, but associated contamination in the orbit and soft tissues. This can result in orbital cellulitis, both a sight- and life-threatening condition (*see* Fig. 9.26).

Fig. 9.26 "Don't blow your nose": two cases of orbital cellulitis (**a**, **b**). Infection can spread rapidly throughout the orbit and extend intracranially and into the face. When it is as extensive as this, the prognosis is extremely poor. Often patients are immunocompromised in some way. Fortunately this is very rare

9.4.1 Surgical Repair

When orbital fractures coexist with other fractures of the midface (zygoma, nasoethmoid, frontal bone), these must be repaired first. This is because safe orbital dissection and successful repair of orbital defects are dependent on key landmarks and a correctly positioned infraorbital rim to support the implant. This will not be possible if the peripheral bones are significantly displaced.

9.4.1.1 Indications for Repair

"Clinically Significant" and the Risks of Surgery

Surgical repair is a controversial area of practice. While some fractures clearly require repair and others clearly do not, there remains a "grey area" in which the need for surgery is largely a matter of opinion. This is partly due to the problems of defining what is "clinically significant" enophthalmos, and in accurately predicting when it will occur in any particular patient. In some patients there may be an obvious orbital floor defect, yet the amount of enophthalmos they eventually develop is less than anticipated. Furthermore, in many cases the patients themselves are not even aware of this. Therefore the need for surgery has to be balanced against the small risks of potentially major complications.

In the absence of any significant diplopia, surgical repair becomes largely a cosmetic procedure (i.e., to prevent or treat enophthalmos). In these patients the concern is that any repair itself could result in complications such as significant diplopia or injury to the visual pathway. Although these risks are very small, should either occur, the patient will be considerably worse off. This needs to be clearly discussed with the patient before surgery is agreed on. The final decision in such "borderline" cases is therefore largely a matter of personal/patient preference, taking into account the risks and benefits of operating (or not). Indications and relative contraindications for surgery are shown in Table 9.4.

Table 9.4 Indications and relative contraindications in orbital repair

Indications	Relative contraindications
Significant restriction of eye movement with CT confirmation of entrapment	Visual impairment Anticoagulant medication
Significant dystopia	Patient not concerned
Significant enophthalmos	Proptosis
"Large" blowout	"At risk" globe

How "Big" Is Big?

If a defect is large enough it will inevitably result in enophthalmos once swelling has fully settled. However, the precise dimensions of a "large" blowout fracture (as measured on CT imaging) are unclear from the literature. A number of studies have looked into the relationship between orbital volume expansion and enophthalmos, each with different findings. Some clinicians feel that any defect greater than 1×1 cm will result in "significant" enophthalmos. However, the site of the defect will probably have as much bearing (if not more) than the actual size. Defects involving the posteromedial bulge are more likely to have greater effect on globe position than similar sized defects sited more anteriorly (*see* Fig. 9.27).

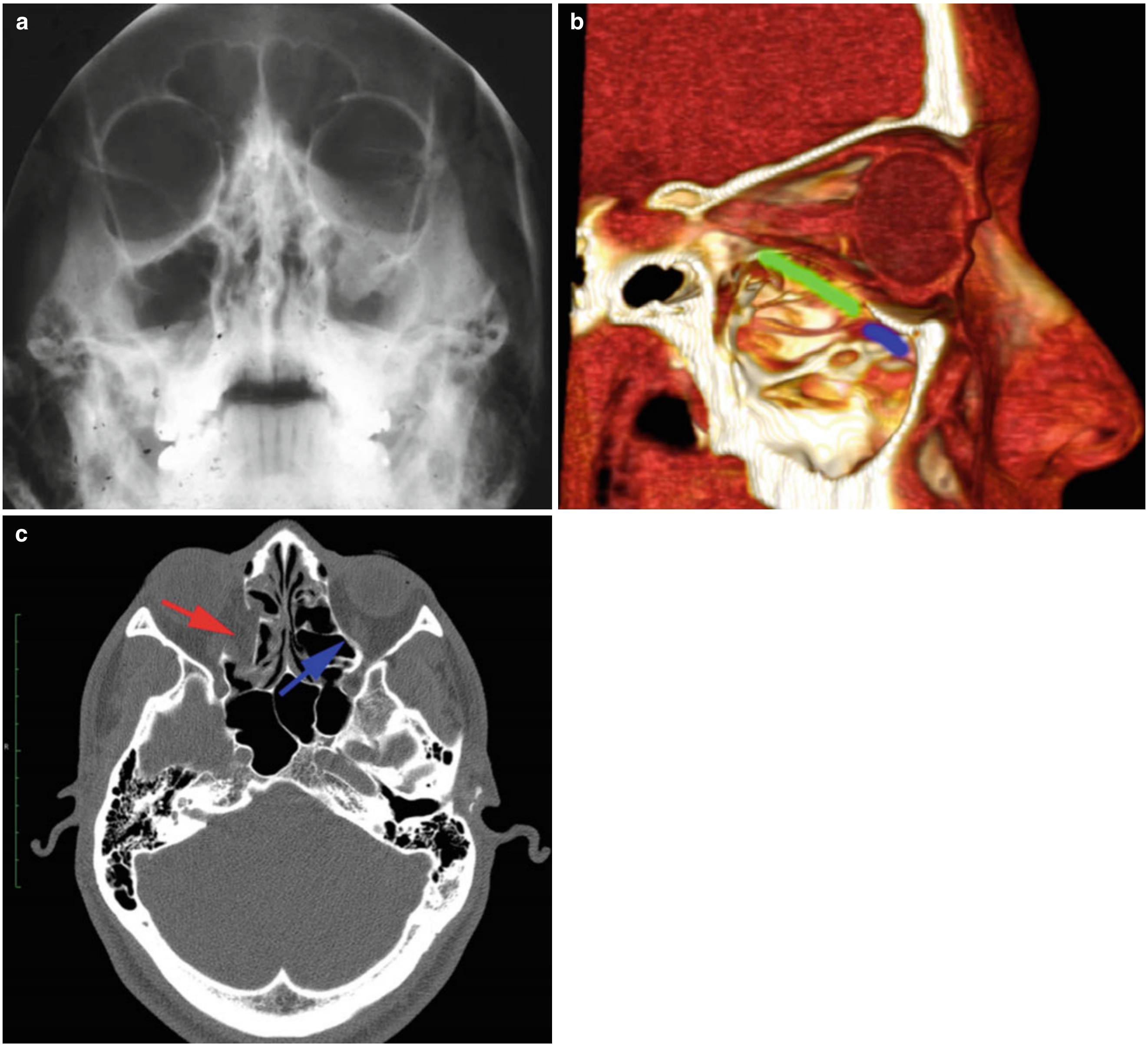


Fig. 9.27 Before the advent of CT, defining the size of an orbital floor defect was impossible. The "hanging drop" sign (**a**) gave no indication of size and tomograms (now obsolete) gave little more information. CT has without doubt significantly improved diagnosis. Defects involving the posteromedial bulge (*green line*/*red arrow*) are most likely to have a significant effect on orbital volume and globe position (**b**, **c**). The *blue arrow* on the axial view illustrates how the convexity of this "bulge" supports the forward position of the globe. Fractures of the posteromedial bulge should be considered as fractures of both the orbital floor and medial wall. Anterior-sited defects below the globe (*blue line*) are more likely to have an effect on the vertical position of the globe. This effect is lessened if Lockwood's suspensory ligament is intact

Today, orbital volumes can be measured using appropriate software after CT scanning. This can provide a valuable tool in the prediction of enophthalmos and evaluation of repair (*see* Figs. 9.28 and 9.29).

When Is Diplopia Significant?

Similarly, opinions vary over what constitutes "significant" diplopia. This is a relatively common clinical finding, although in many patients it occurs only at the extremes of

gaze. Diplopia is usually more of a clinical problem when looking downwards (for example to read), but in some professions diplopia on looking up can be just as much a problem (e.g., for a heavy goods vehicle, or bus driver, or professional snooker/pool player). Fortunately, in many cases this will resolve if managed nonsurgically and eye movements are encouraged.

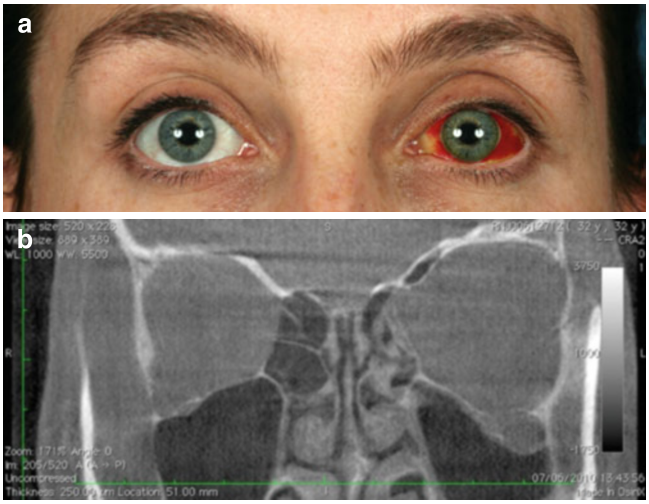


Fig. 9.28 A two-wall defect involving the lateral orbital floor and medial wall (**a**, **b**). Enophthalmos is already apparent

Deciding when (and when not) to operate is therefore not always that simple. In some cases a period of close follow-up may be necessary to determine if any of the initial symptoms and signs are resolving (diplopia) or getting worse (enophthalmos). Since surgical repair always carries the small (but devastating) risk of blindness and causing diplopia, a clear indication for surgery should always be established.

9.4.1.2 Timing

Timing of surgery is dependent on a number of factors. Immediate exploration and repair is rarely required. However, many authorities believe that indications for urgent repair include significant entrapment of the *muscles*. In most "blowouts" it is the orbital fat that is trapped. However, muscle entrapment (which can be seen on coronal CT views) can potentially result in ischaemic injury to the muscle and subsequent fibrosis. Inappropriately severe pain is considered by some to be a sign of this. The pain is severe because of ischaemia (cf pain in myocardial infarction, or an ischaemic leg). For similar reasons, blowout fractures in children may need to be repaired urgently if they are accompanied by severe pain (and often vomiting). Due to the greater elasticity in young bone, children are more likely to experience entrapment (since the bones recoil back into place). This can result in severe restriction in eye movements. Entrapment in the

Fig. 9.29 The dimensions of the defects have been measured. Appropriate software can calculate the volume change at both sites separately and collectively. This helps in predicting the extent of enophthalmos and in planning repair (**a–c**)

absence of external signs of trauma has been termed the "white-eyed blowout fracture" (WEBOF).

> Diagnosis of WEBOF is important and can be easily overlooked. Attempts to examine the eye may generate significant pain and a parasympathetic autonomic response, resulting in nausea, vomiting, and bradycardia. These symptoms can be easily misinterpreted, especially if there is a history of head injury and there are no external signs of orbital trauma.

In the absence of indications for urgent repair, most blowout fractures can be left safely for up to 7–10 days if necessary. Swelling should be allowed to resolve to enable further assessment. Repairing a blowout fracture in the presence of significant swelling may put the patient at risk of developing orbital compartment syndrome postoperatively. While the orbital wall defect is present, oedema can leak out of the orbit and fat can herniate if the pressure is high (effectively decompressing the orbit). However, once repaired this natural compensation is lost.

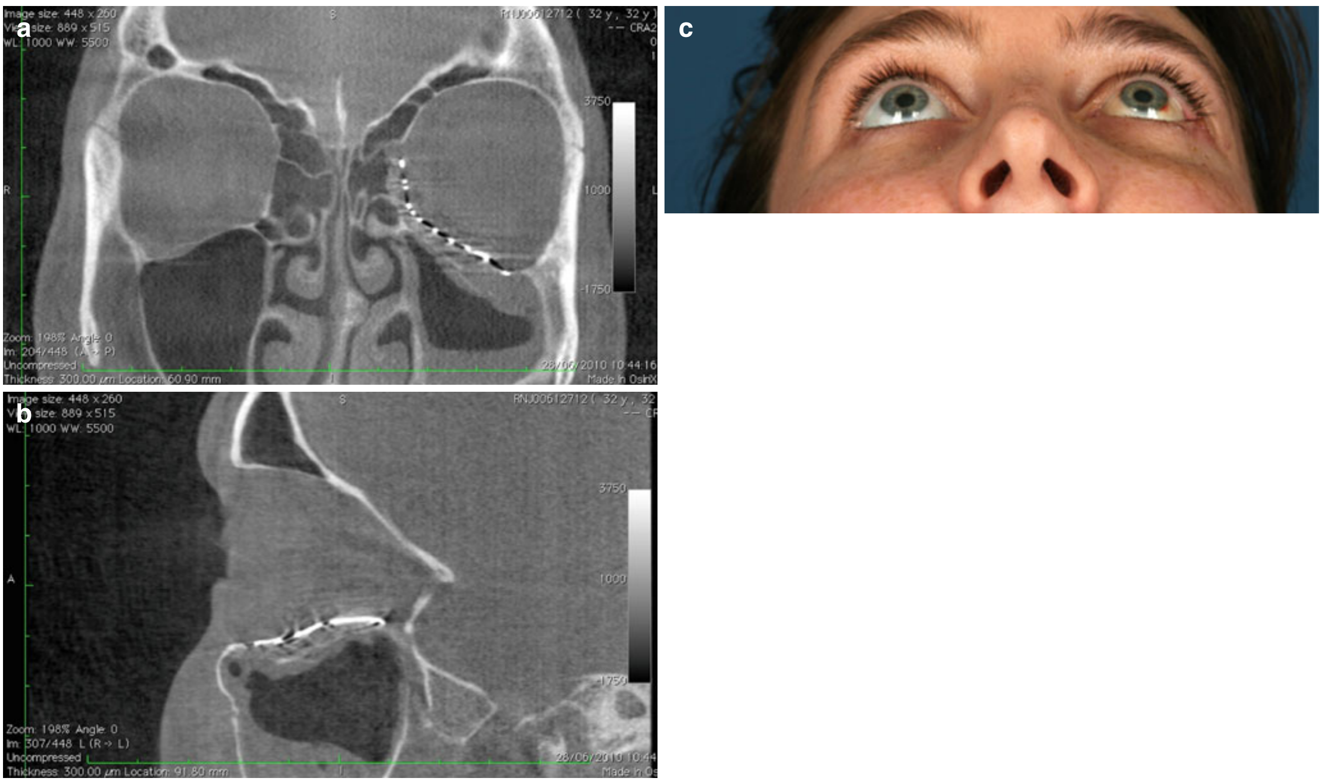


Fig. 9.30 Postoperative CT images with successful correction of enophthalmos (**a**–**c**)

9.4.1.3 Infraorbital Access

Access to the infraorbital margin is commonly required during repair of midface fractures, fractures of the zygoma, or in the exploration and repair of orbital floor fractures and some fractures of the medial wall. A number of approaches are well described in the literature and which approach is taken depends on a number of factors (surgeon's and patient's preference, overlying lacerations, access required, presence of suitable skin creases, to name a few). Collectively these can all be considered as falling into two groups: transcutaneous or transconjunctival. Both are relatively quick procedures (*see* Figs. 9.31 and 9.32).

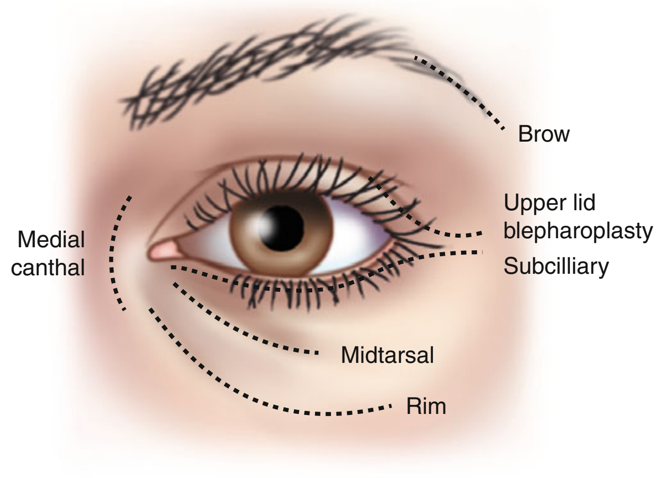


Fig. 9.31 Transcutaneous approaches to the orbit. Variations of these exist. Some may be made "straight down to bone," or the approach may be stepped, with the incision of each successive layer at a different level

Transcutaneous Approaches

Transcutaneous approaches have a number of advantages and disadvantages and arguably may be a safer approach for the novice. A number of skin incisions have been described, ranging from the "subciliary" incision, which is placed just below the eyelashes, to the lower "subtarsal" (or rim) incision, which is placed along the lower edge of the eyelid. Much has been written about the relative merits of each (*see* Fig. 9.31).

Midtarsal Approach

In the first two cases shown, an incision approximately midway between the subciliary and subtarsal levels has been made: "midtarsal." This has been sited in a suitable skin crease. Meticulous haemostasis is required during this procedure. Not only does this help with the dissection of the tissues, but it also minimises postoperative bruising and swelling of the eyelids. Following an initial full-thickness skin incision, the wound edges are gently retracted with skin hooks. Forceps should not be used to grasp the skin as it is easily damaged. Using fine tenotomy scissors, the muscle fibres of the underlying orbicularis muscle fibres are gently separated, proceeding towards the infraorbital margin. (Some surgeons approach the orbit through a "stepped" incision. This is reported to improve scarring.) In most cases this is a "muscle splitting" type procedure, in that the muscle fibres can be separated without being divided. Consequently there is usually very little bleeding. However, with medial or lateral extensions of the incision, some division of muscle fibres may be necessary due to their circular configurations. This should be kept to an absolute minimum and is usually avoidable with careful retraction of the muscle fibres.

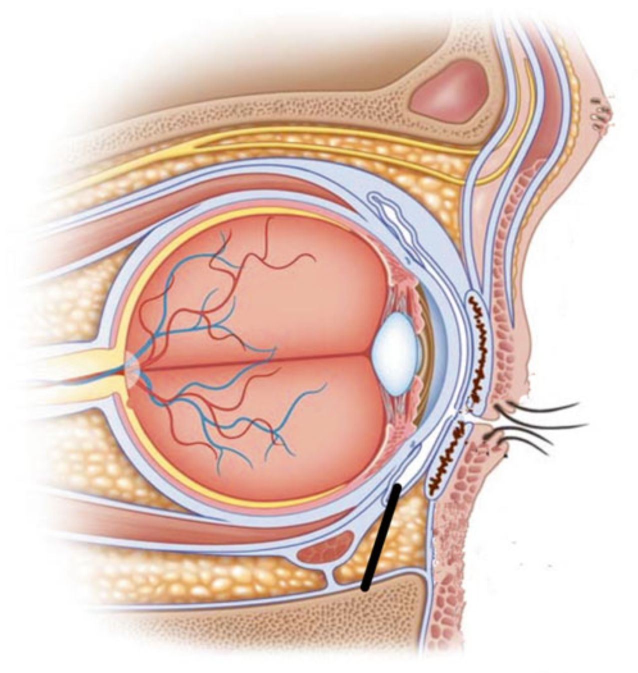


Fig. 9.32 Transconjunctival approach to the orbit. These can be 'retroseptal' (as shown here) or 'preseptal'

Splitting of the muscle fibres exposes the underlying orbital septum and periosteum. These are then incised with a scalpel along the entire length of the infraorbital rim, a few millimetres below the crest. Care is required at this stage, particularly in the presence of multiple bone fragments, as these can be mobile and easily displaced by pressure from the scalpel blade. Using a sharp periosteal elevator, the periosteum is then gently lifted. Care is also required during this part of the procedure as the infraorbital nerve is often encountered during periosteal elevation, both within the orbit as well as exiting from its foramen. The position of the nerve can vary, so it must be carefully looked for during this part of the procedure. Deep orbital dissection is described later.

Following repair of the rim and/or orbital defect, the periosteum is carefully closed with a resorbable suture. If extensive exposure of the midface has been undertaken, the soft tissues need to be resuspended. This can often be achieved using the fixation plates as a point of anchorage.

Case 1

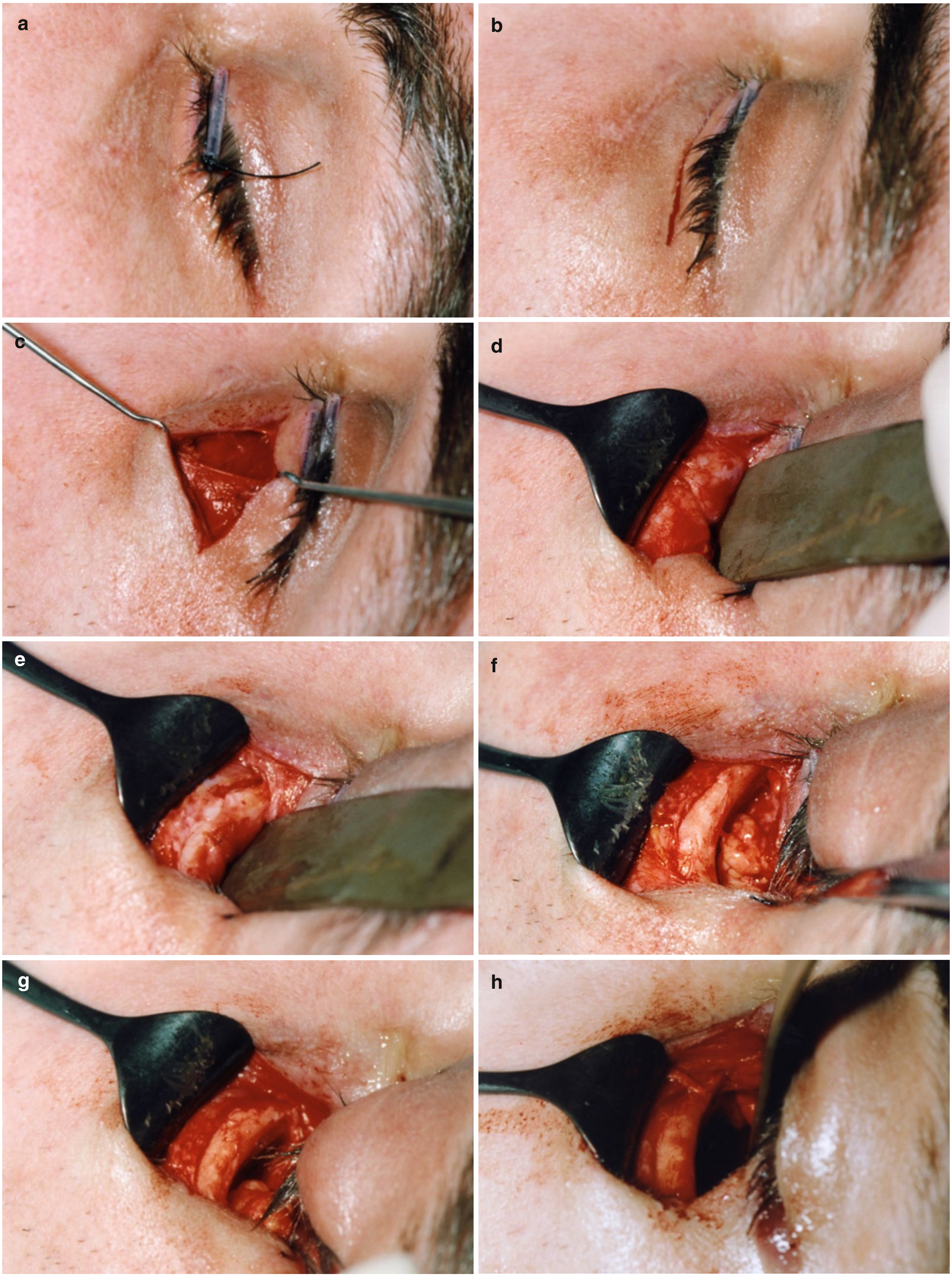


Fig. 9.33 (**a**–**h**) Mid tarsal approach to the orbit. Following a temporary tarsorrhaphy, the midtarsal incision is made. Upward traction stretches the lower eyelid skin and helps placement of the incision. The skin is gently separated with skin hooks and the muscles split (either directly below or in a stepped fashion). Following periosteal incision and elevation, the defect can be defined

Case 2

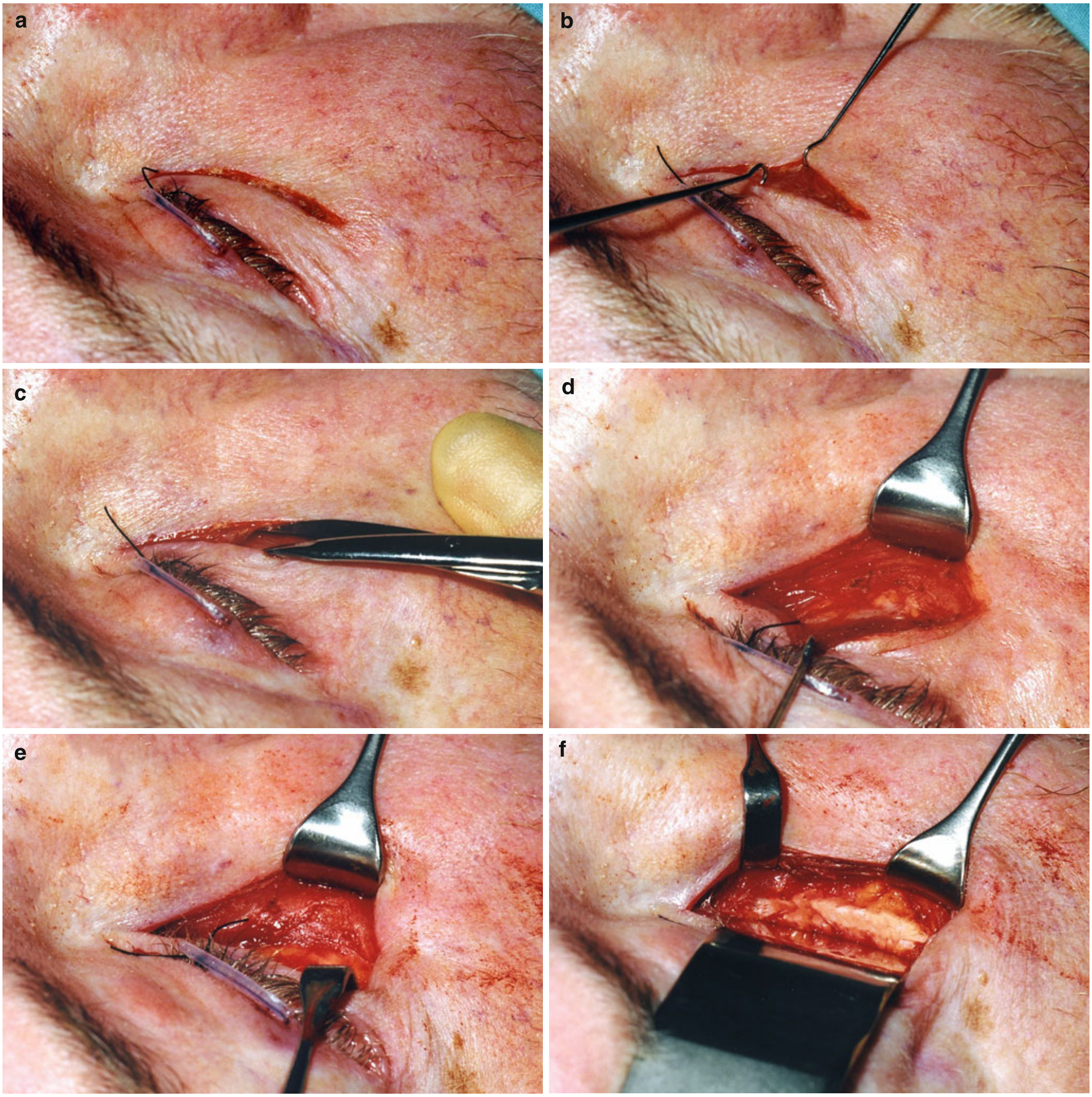


Fig. 9.34 (**a**–**f**) Mid tarsal approach to the orbit. Following skin incision the edges are gently retracted using skin hooks. Muscle splitting with fine tenotomy scissors is usually quick and causes very little bleeding. The periosteum in the incised and elevated

Case 3

In some cases, access to the infraorbital margin may be possible through a preexisting laceration. The dissection through the laceration itself follows the same principles as previously described. However, the anatomy can sometimes be more confusing due to the presence of soft tissue injury.

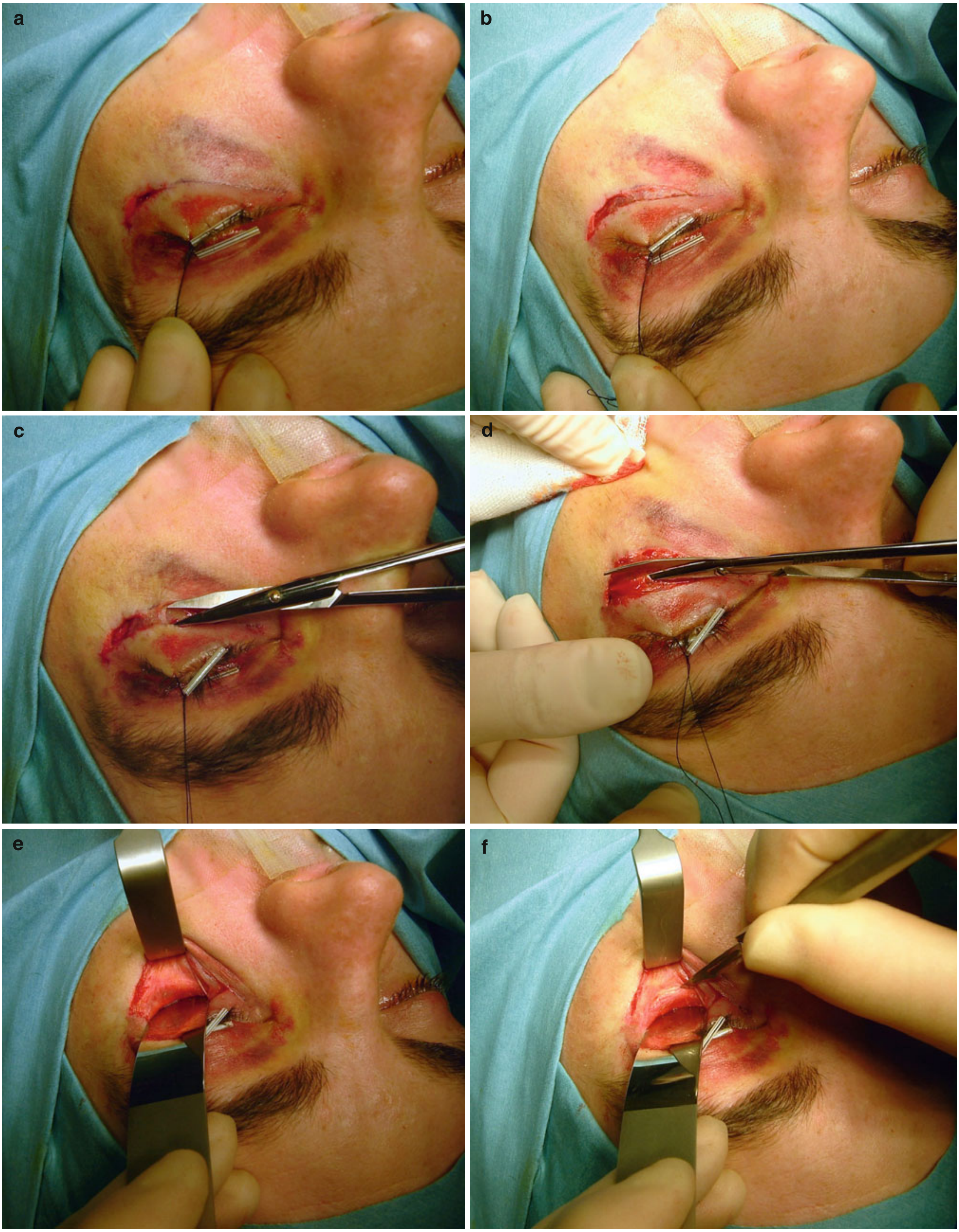


Fig. 9.35 The laceration is extended medially within a suitable subtarsal skin crease (**a**, **b**). Following skin incision the muscle fibres are bluntly separated as previously described (**c**, **d**). This provides extensive exposure of the underlying bones (midface and orbital fractures in this case). The periosteum is then incised (**e**, **f**)

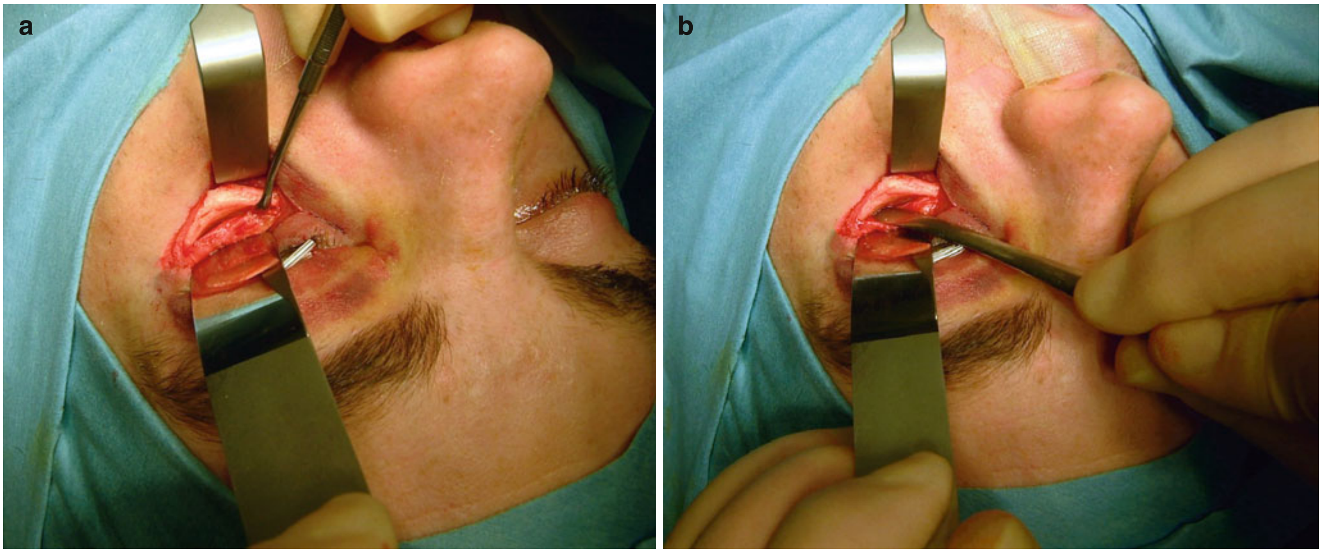


Fig. 9.36 The periosteum must be elevated carefully, avoiding “buttonholes” in the process. Once in the correct plane it usually elevates easily (in areas remote from the fractures). Start laterally (**a**, **b**)

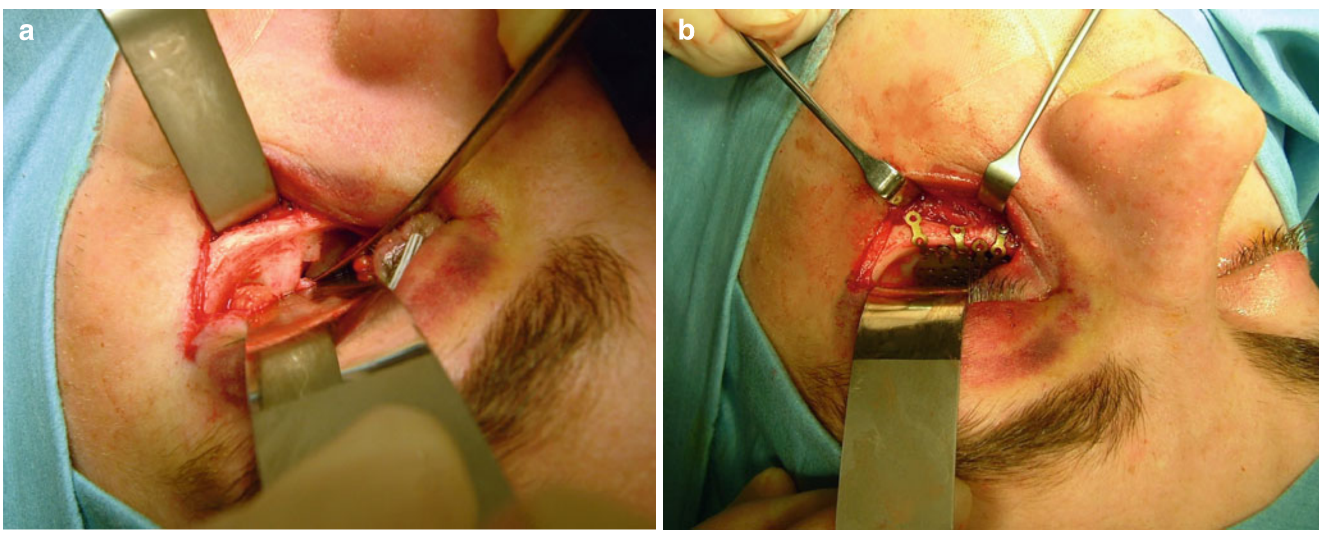


Fig. 9.37 The defect is then defined and repaired. With such extensive exposure careful resuspension of midface tissues is important during closure (**a**, **b**)

Transconjunctival Approaches

A number of transconjunctival approaches to the orbit have been described in the literature. These can be considered as either "preseptal;" that is, part of the dissection proceeds superficial to the orbital septum and tarsal plate, or "retroseptal" where the entire dissection proceeds deep to the tarsal plate. Even retroseptal approaches have variants (*see* Fig. 9.32).

Retroseptal Approach

The retroseptal approach is one of the simplest and most direct approaches to make. A low conjunctival incision can be placed deep in the fornix, just above the orbital rim. Alternatively, an incision can be placed at a slightly higher level and a conjunctival flap raised. This can be used to protect the globe. Each has advantages and disadvantages over the other, and which is used is largely a matter of personal choice.

In the examples shown, access to the orbit has been gained through an incision placed low in the fornix. A protective eye shield is required for this approach. Gentle retraction is important here. The lower eyelid is retracted and a malleable flat retractor is used to gently retract the globe and conjunctiva, such as to stretch the conjunctiva over the infraorbital rim. Very often a thin layer of orbital fat can be seen and felt bulging into the fornix. In younger patients this can sometimes be gently "milked" back into the orbit, although a small amount commonly herniates through the incision (this is not a clinical or technical problem). To minimise this from occurring, the first incision can be made through the conjunctiva only, not straight down to bone. Conjunctiva is surprisingly thicker than often thought. Any bleeding is stopped and the malleable retractor then replaced, retracting any fat that is now clearly visible.

A second incision is then made through the remaining tissues and periosteum. This incision can be a little bit difficult if the orbital rim is comminuted and there are "floating" fragments. However, if the bone is well supported, this is an easy approach to make. Once the periosteum is incised, it is elevated along the length of the rim (*see* Figs. 9.38, 9.39, 9.40 and 9.41).

Case 1

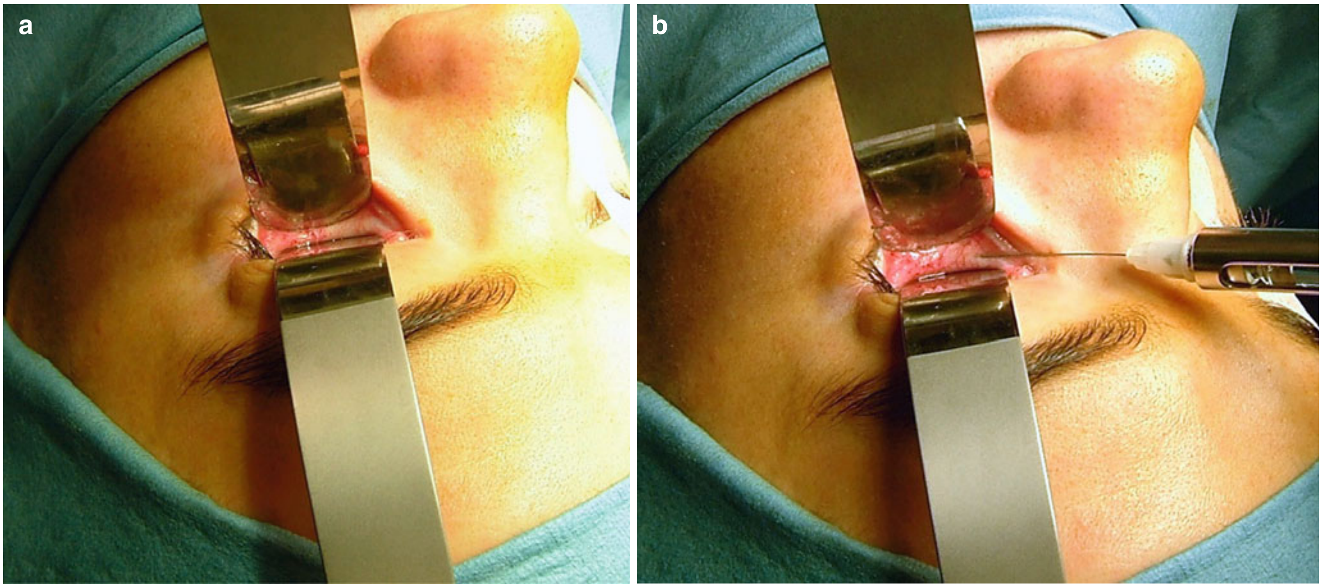


Fig. 9.38 Gentle retraction of the lower eyelid and globe stretches the conjunctiva over the rim. Local anaesthetic is infiltrated. Haemostasis greatly facilitates dissection (**a**, **b**)

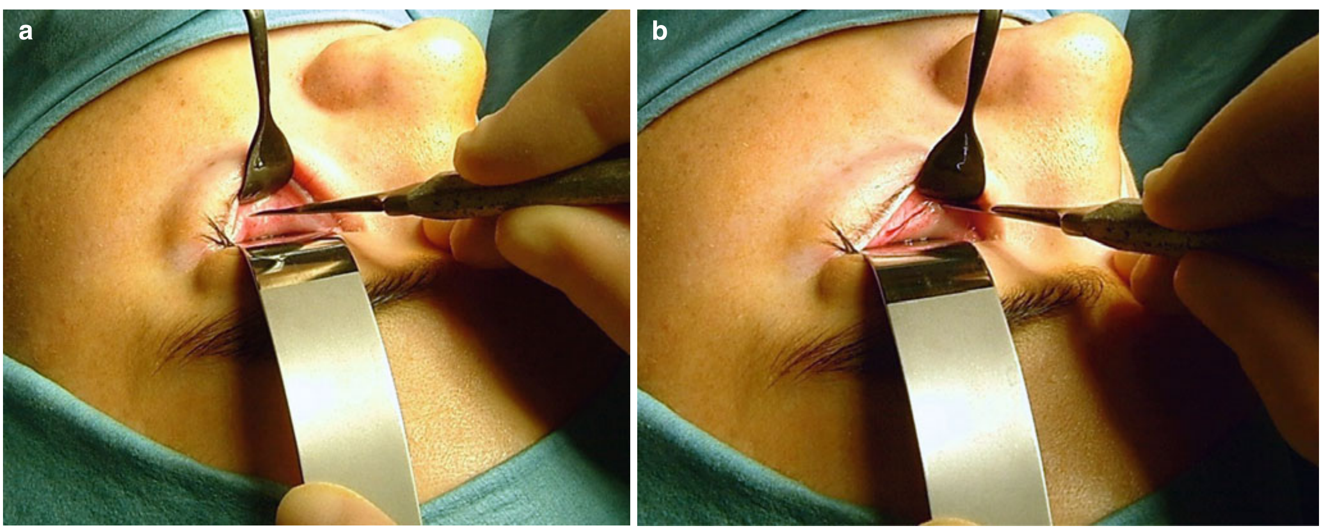


Fig. 9.39 The conjunctiva is incised, either directly “down to bone” or as a full-thickness conjunctival incision only (as here) (**a**, **b**)

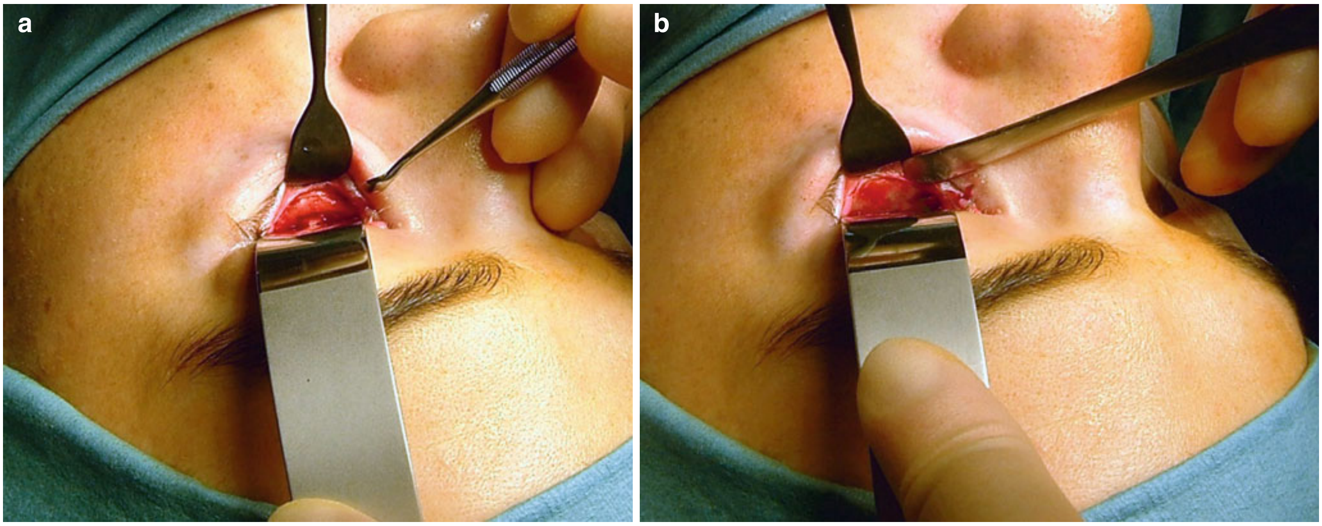


Fig. 9.40 The underlying soft tissues and fat are gently "milked" into the orbit and a second full-thickness incision made to include periosteum. This is then gently elevated (**a**, **b**)

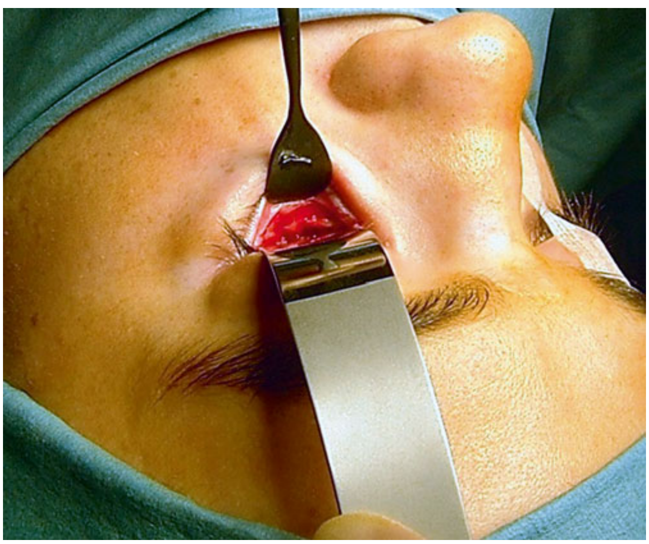


Fig. 9.41 The retroseptal approach is very quick, but only gives limited access (depending on how lax the lower eyelid is). This is considerably improved when combined with a lateral canthotomy (described later)

Case 2

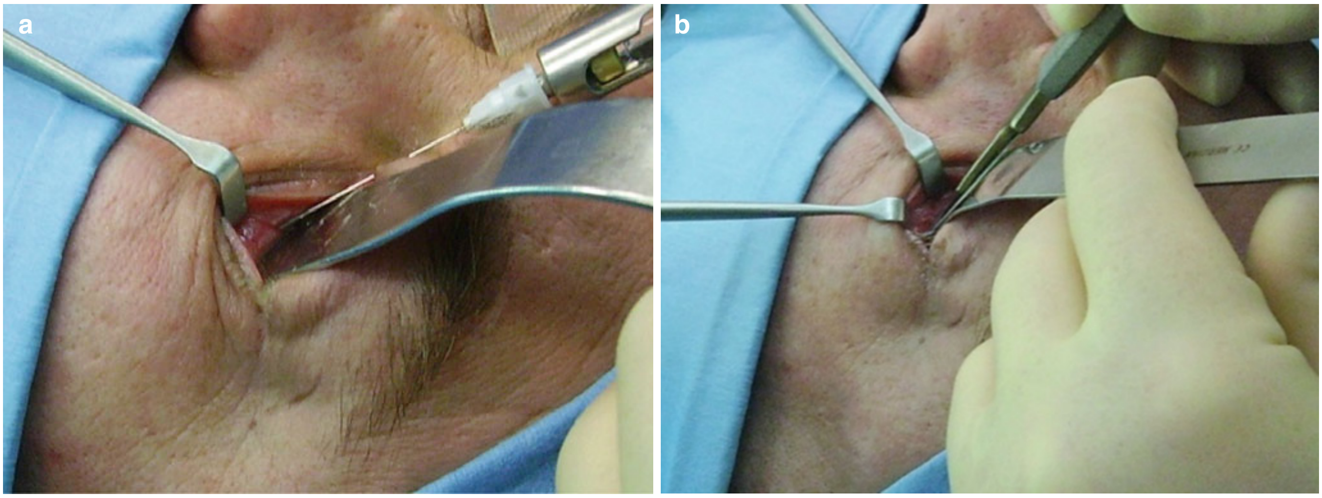


Fig. 9.42 Injection of local anaesthetic and incision (**a**, **b**)

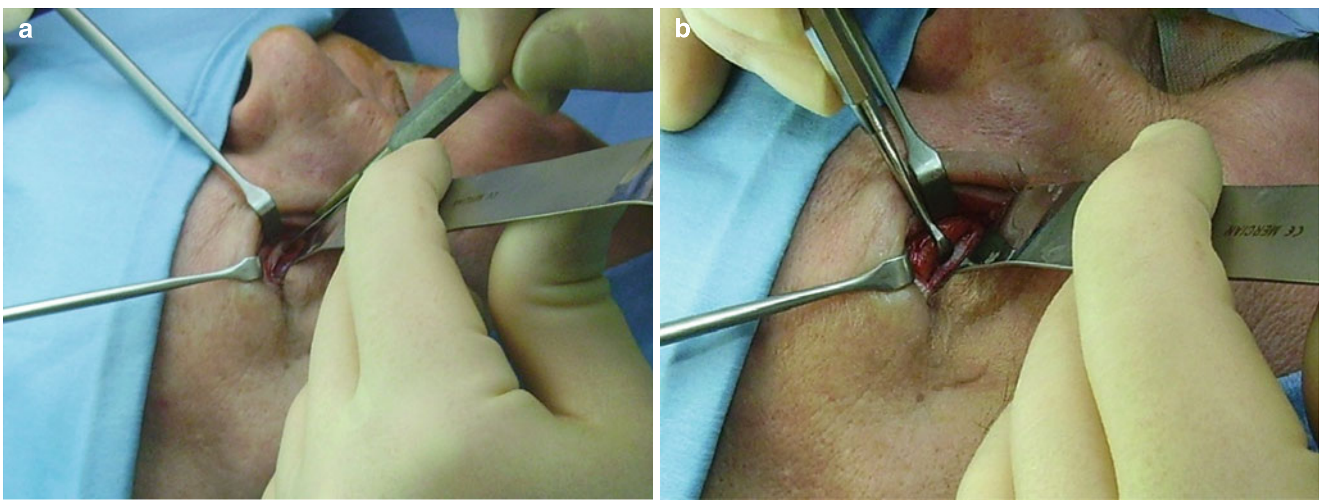


Fig. 9.43 Second periosteal incision and elevation of periosteum (**a**, **b**)

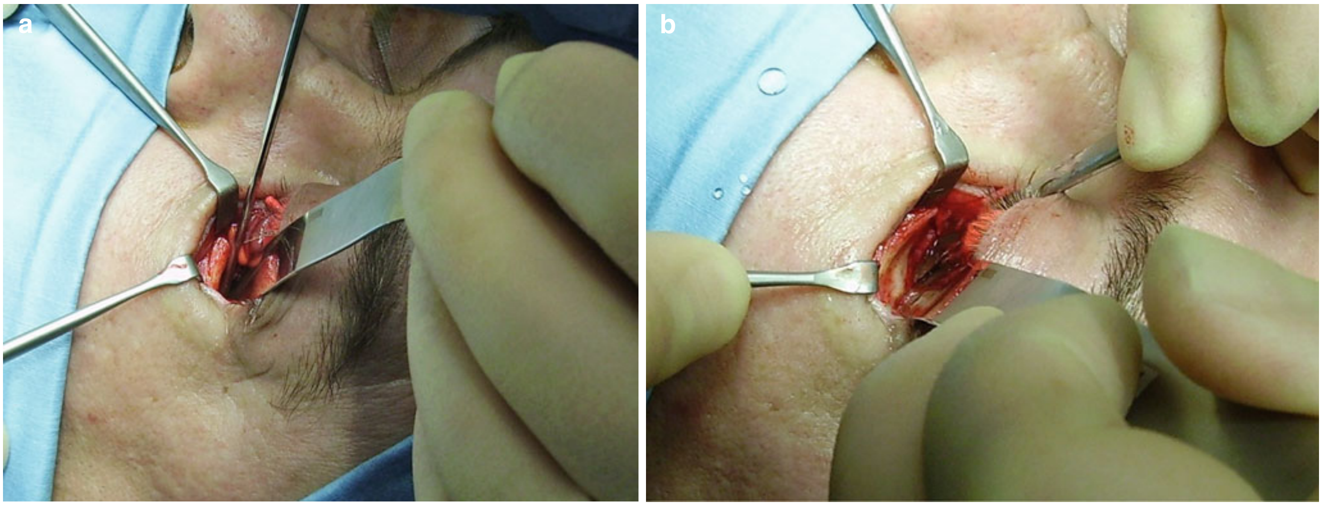


Fig. 9.44 Without a lateral canthotomy, small defects can usually be repaired (**a**, **b**). Note protective eye shield. These can easily displace

Depending on the extent of periosteal elevation, the periosteum may be sutured at the end of the procedure or not. Suturing the periosteum would be recommended if extensive dissection onto the cheek has been required (to help resuspend tissues), or if an implant has been placed, but not securely fixed (e.g., silastic sheeting). The conjunctiva can either be sutured or not (*see* Fig. 9.45).

The retroseptal approach has the merits of being very quick and providing reasonably good access. However, orbital fat can sometimes herniate into the wound and irritatingly get in the way. The lower eyelid retractors can also be affected by this approach if the wound is poorly designed or closed. For this reason some surgeons prefer not to suture the conjunctiva.

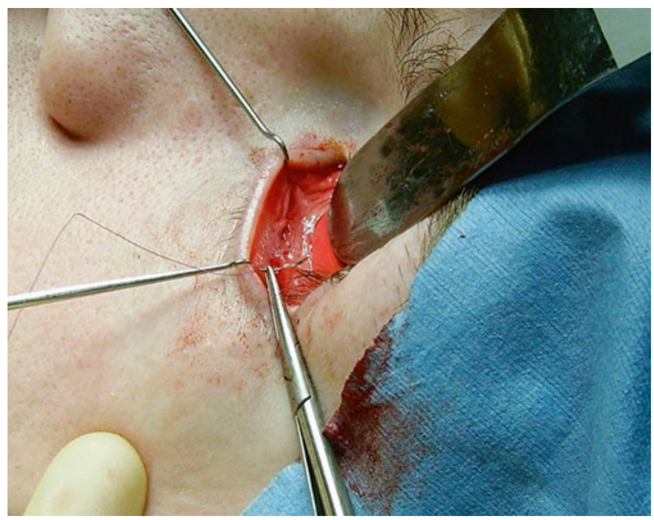


Fig. 9.45 The conjunctiva can be closed with a resorbable suture (6.0 Vicryl in this case). The knots should be buried

Preseptal Approach

In the preseptal approach, an incision is made through the conjunctiva, below the tarsus. A plane of dissection is then developed between the more superficial orbicularis muscle and the orbital septum.

The initial incision can be done with a scalpel or a guarded monopolar cautery needle (Colorado needle). The plane of dissection deep to conjunctiva is developed with scissors and a retraction suture placed through the free margin of the flap. This is gently retracted superiorly over the globe. The dissection is continued inferiorly between the orbital septum and the overlying orbicularis oculi muscle. This is a relatively avascular plane. It is important to keep the orbital septum intact as this prevents herniation of orbital fat or injury to the inferior oblique muscle. Once the orbital rim is exposed, the periosteum is incised and elevated. Following exploration, the wound can be sutured or left.

Left transconjunctival incision with secondary cantholysis and McCord lid swing (*see* Figs. 9.46 to 9.49 and 9.51 to 9.53).

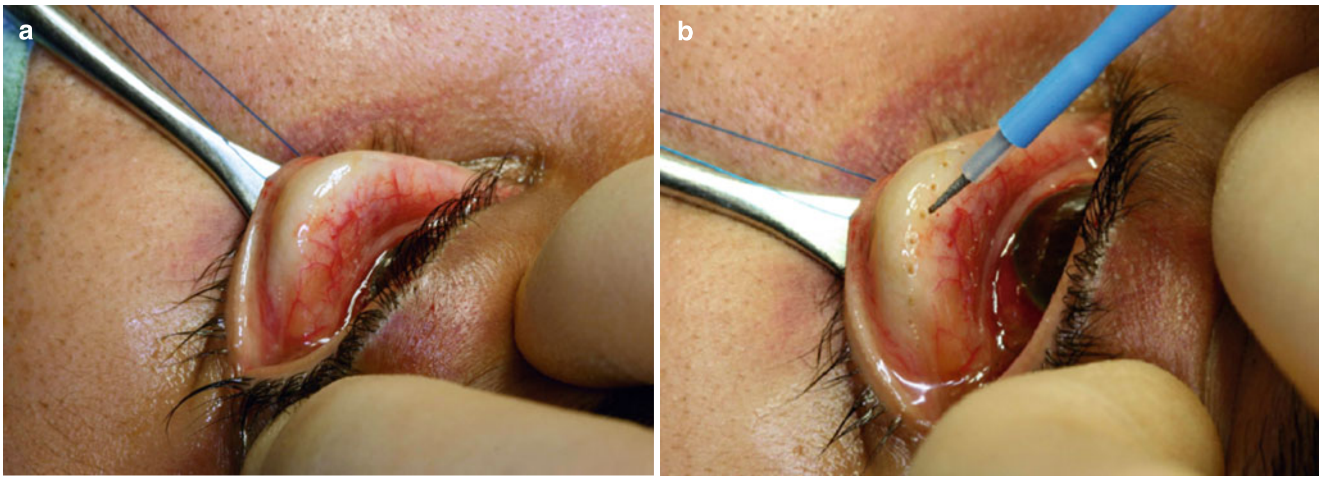


Fig. 9.46 The initial incision is made using cutting diathermy, using a "postage stamp" technique (**a**, **b**)

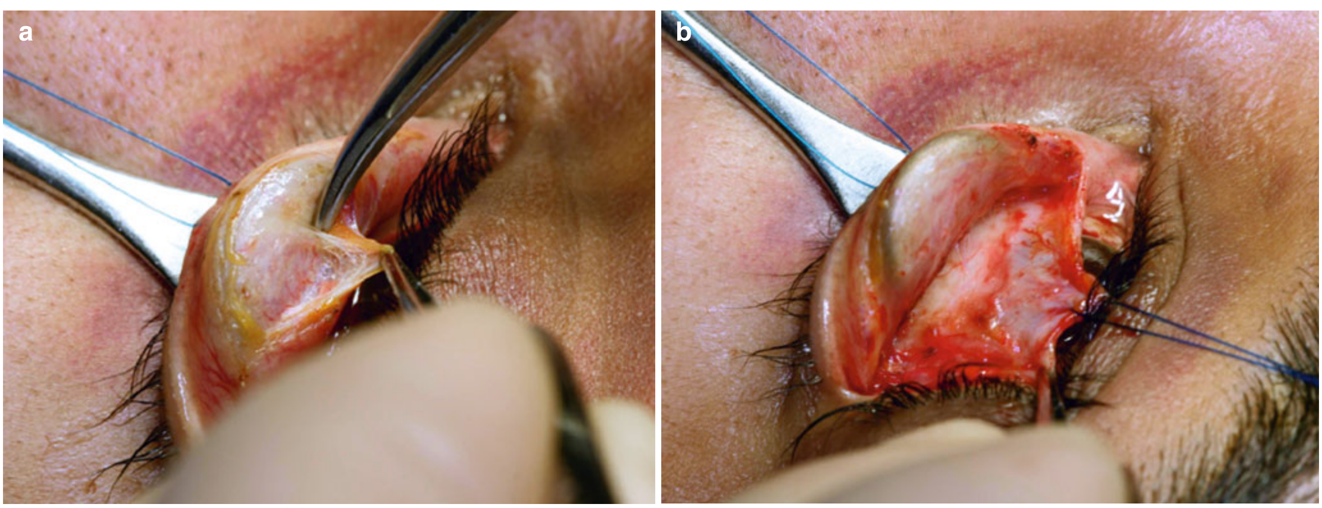


Fig. 9.47 A conjunctival flap is raised (**a**). As the dissection proceeds, any vessels in the conjunctival connective tissue are readily displayed. Both sharp dissection with scissors and/or cutting diathermy may be used. The conjunctival flap is used to protect the globe (**b**)

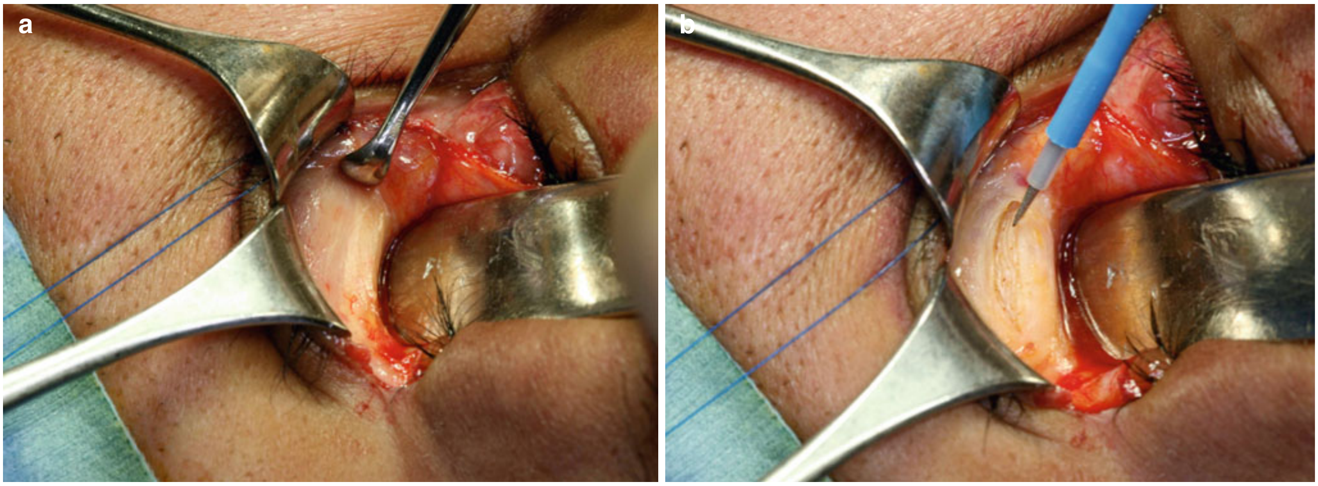


Fig. 9.48 Once the periosteum is clearly exposed, it is incised with a cutting diathermy. If any thickness or “sponginess” of the soft tissue is observed, continue with the blunt dissection (**a**, **b**). Otherwise the skin flap, which is very thin, may be buttonholed

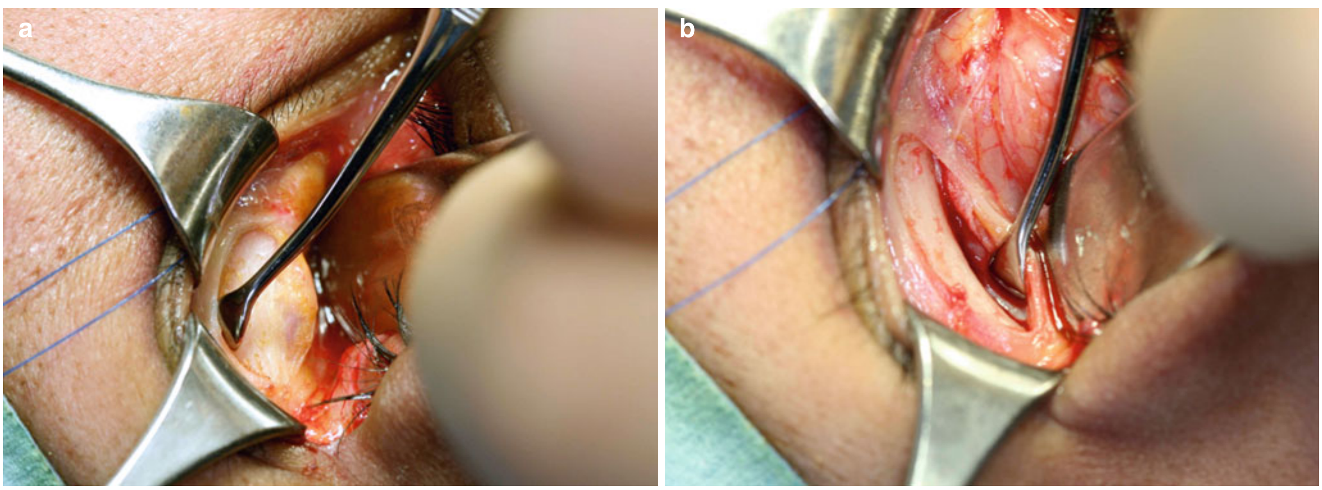


Fig. 9.49 The rim is fully exposed and the orbital periosteum then elevated, commencing laterally and working across the rim and deep towards the inferior orbital fissure (**a**, **b**)

Improving Access: Lateral Canthotomy (See Fig. 9.50)

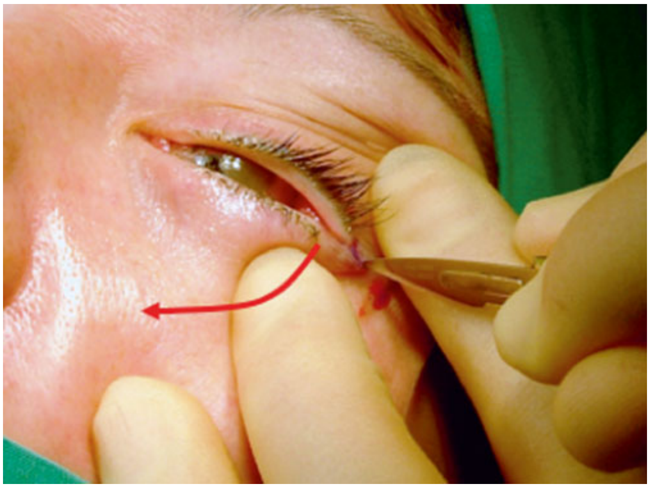


Fig. 9.50 The addition of a lateral canthotomy to either of the transconjunctival approaches considerably improves access. In experienced hands it is a quick procedure with minimal morbidity. Meticulous closure is required, however

Most small to medium-sized blowout fractures can be accessed comfortably through either of the transconjunctival incisions just described. However, with large or complex defects, greater exposure maybe required. This can be achieved by extending the transconjunctival incision laterally, with a lateral canthotomy. Some surgeons prefer to do this part of the procedure before the transconjunctival incision and dissection. Others extend the conjunctival incision as required.

The cutaneous incision of the lateral canthotomy is made using either scalpel or scissors. This is placed at the junction of the upper and lower lids, extending approximately 5 mm laterally, in a suitable "crows-foot" wrinkle. The skin is gently dissected, exposing the inferior crus of the lateral canthal tendon. This is then divided using scissors or scalpel and the deeper conjunctiva incised to join with the orbital incision (*see* Figs. 9.51–9.57).

This simple procedure improves access considerably, as the lower lid hinges downwards. Although it is simple to make, it is very important to accurately realign the tendon when closing the wound.

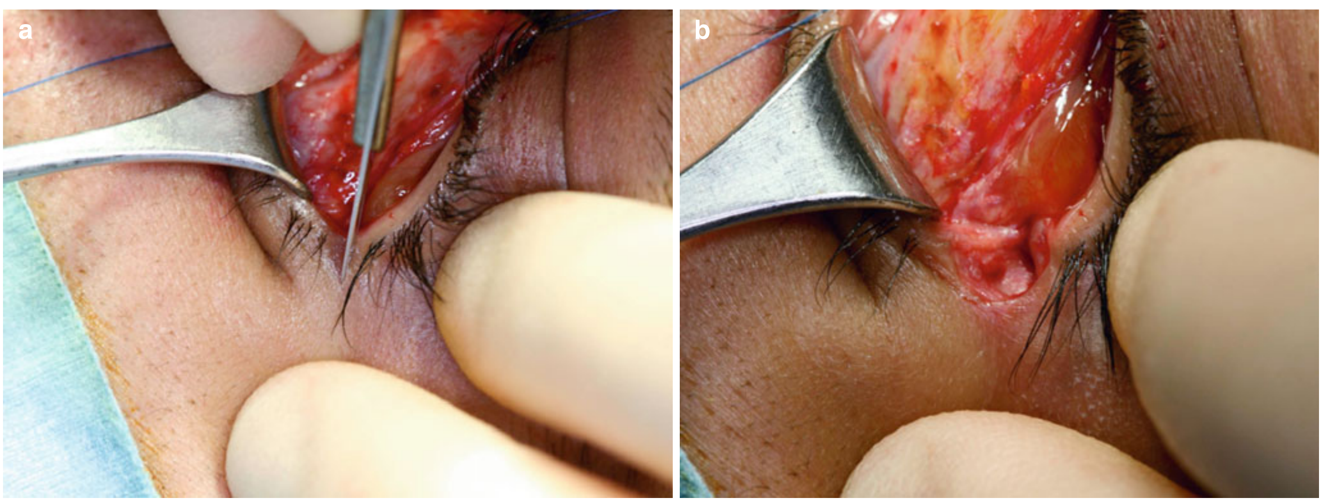


Fig. 9.51 Once the lateral aspect of the conjunctival incision is reached, a small skin incision is made (**a**). It is important to only cut skin at this point. Often there is a small amount of conjunctival oedema (**b**). This can cause some confusion with the anatomy

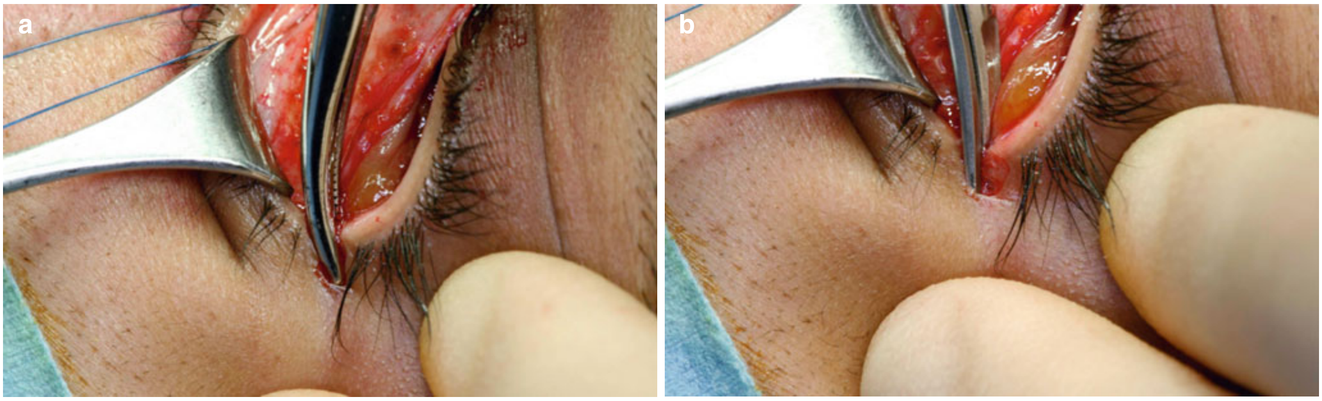


Fig. 9.52 A curved mosquito clip is placed across the tendon; the curve of the clip should point upwards. The aim is to section the lower limb only, thereby leaving the superior limb intact to suture to, minimising lid malposition (**a**, **b**)

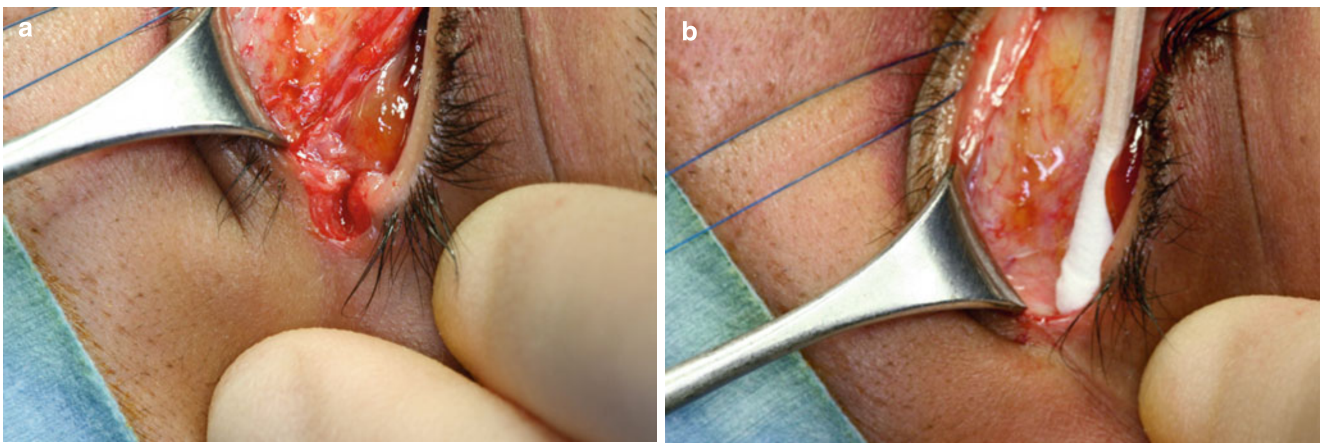


Fig. 9.53 The cut end of the tendon is usually clearly seen (**a**). The Desmarres retractor is now pulled inferolaterally and any remaining vestiges of the tendon displayed and incised. There should be a visible “give” as the tendon parts and the lid swings down (**b**). Without this movement, the procedure is not complete

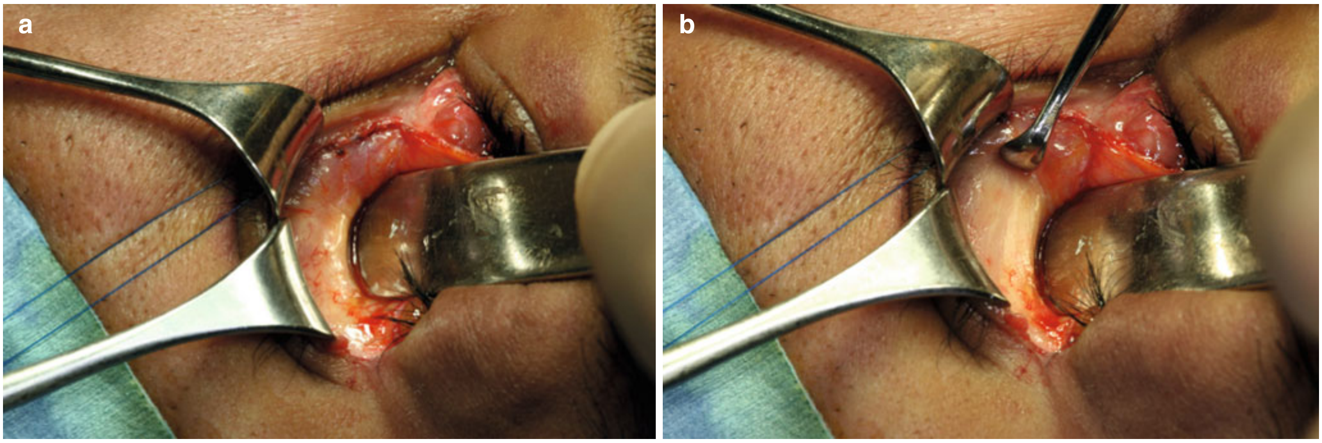


Fig. 9.54 A second Desmarres retractor can now aid the swinging of the lid inferiorly (**a**). A malleable retractor is then placed on the bone edge and rolled posteriorly (**b**). If the rim is broken, then the bone is elevated and supported prior to periosteal incision. Initial dissection should ideally proceed from a solid segment of bone, otherwise there can be considerable fat herniation

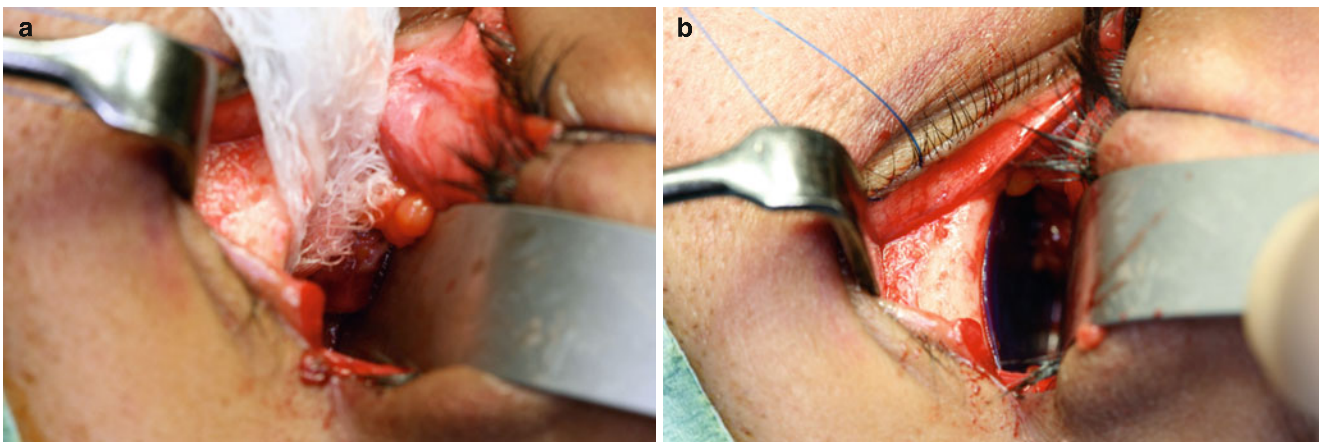


Fig. 9.55 This additional procedure facilitates direct access to the back of the orbit and visualisation of most of the medial and lateral orbital wall as required (**a**, **b**)

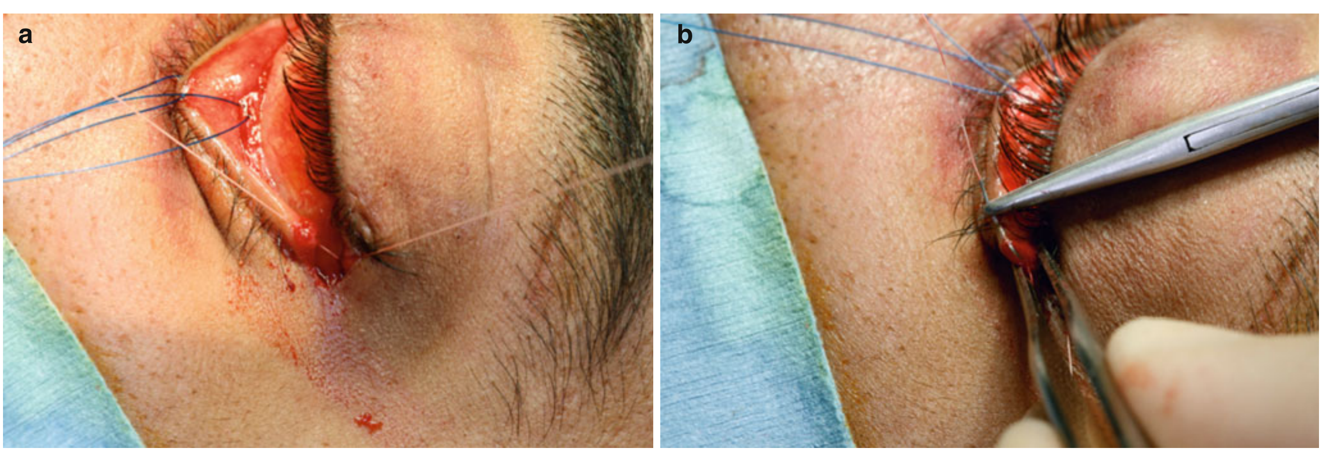


Fig. 9.56 Meticulous closure of the tendon is essential (**a**, **b**)

Fig. 9.57 If the tendon has been accurately repositioned and supported, the skin incision can be left or lightly sutured (**a**–**c**)

Preseptal Cantholysis

With experience, surgical access may be planned to include cantholysis from the outset. There are distinct advantages in this approach, access is considerably improved, and the conjunctival incision is much easier (*see* Figs. 9.58–9.66). Indications for cantholysis include:

- Medial wall fractures
- Comminution of infraorbital margin
- Lateral orbital margin fractures
- Large floor defect
- Young patients: nondistendible lids
- Asian eyes
- Associated repaired lower lid laceration
- Repaired intraocular damage
- Retrobulbar haematoma

Fig. 9.58 The incision is marked in a crow's foot. It is important to dry the skin thoroughly, as there is a tendency for tears to spill and blur the marking. The length of the incision is a matter of experience, and depends on the volume of surgical exposure. In practice the incision can be quite short, as long as the lateral canthal tendon is fully released. Usually around 4–5 mm is all that is required

Fig. 9.59 The incision is just through skin only, just short of the conjunctival edge medially. Bleeding is usually minimal. The index finger and thumb can be used to spread the skin incision to aid development of the cut

Fig. 9.60 Following skin incision, a mosquito haemostat is placed across the canthal tendon. This is used to crush the tissues for around 30 s to ensure that the marginal artery of the lid goes into spasm. Be careful not to let the clip drop over the cornea

Fig. 9.61 Following removal of the clip, the canthal tendon is incised with a pair of sharp tenotomy scissors, or curved Aufrecht scissors. It is important that the sharpest scissors are used. If the cut is not achieved easily, it is better to open another instrument set rather than to simply chew away with blunt ones. Or use a scalpel

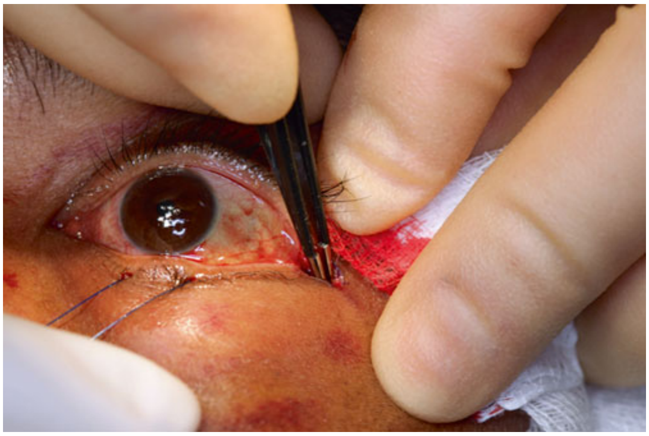


Fig. 9.62 Invariably there is a troublesome vessel in the bed of the incision. Bipolar diathermy is used to arrest this. However, if bleeding is minor, it may be easier to carry out haemostasis once the conjunctiva has been raised

Fig. 9.64 Cutting diathermy greatly facilitates bloodless dissection. However, conventional micro-scissors may also be used. Further dissection proceeds as previously described

Fig. 9.63 The lid is then everted over a Desmarres retractor. In contrast to secondary cantholysis, the lid is much easier to evert. It is also more straightforward to maintain an even cuff of conjunctiva. Postage stamp incisions are made. Leave a cuff below the tarsal plates to suture back, and finish medially just behind the caruncle (**a**, **b**)

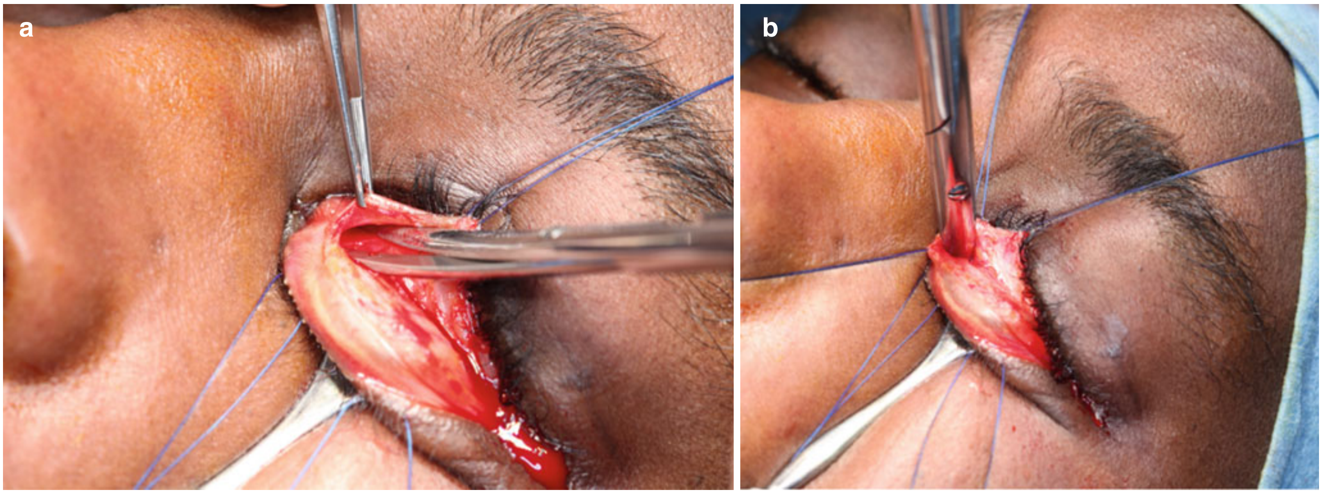


Fig. 9.65 Traction sutures facilitate conjunctival dissection. As the incision is developed, the lid moves gently caudally (**a**, **b**)

Fig. 9.66 Whilst meticulous closure essential, a small gap is useful to allow egress of blood following extubation

Other Approaches

Historically, the "antral pack" was a commonly employed technique in the management of isolated blowout fractures. A "transantral" approach provided access to the undersurface of the orbital floor via the maxillary sinus. Packing the sinus reduced and supported the floor, allowing it to heal. An incision was made in the upper labial sulcus to expose the anterior maxillary wall. Through this, a Caldwell-Luc antrostomy was made using a drill or osteotome. The antrostomy was then enlarged (remembering to protect the infraorbital nerve), until it was large enough to provide access to the orbital floor. The antrum was then gently packed. Following repair of the fracture, the mucosa was closed with a resorbable suture (*see* Figs. 9.67 and 9.68).

Unfortunately, this was a very imprecise technique, best suited for small defects with no entrapment. Leaving the packs in situ for several weeks carried the risk of infection. Packs were removed several weeks later, through the same incision. Due to these limitations, this technique has now largely been replaced by open techniques, but it is still worth knowing about.

Fig. 9.67 The antral pack was once a popular method of treating orbital floor fractures. However, it lacked precision and packs could get infected. This is now largely an obsolete technique, but is still worth knowing

Fig. 9.68 Antral packing following support of the zygomatic fracture with an external fixator

Successful use of endoscopic-assisted approaches via a transmaxillary and transnasal route has also been reported.

9.4.1.4 Deep Orbital Dissection and Placement of Implants/Grafts

Be aware of the oculocardiac reflex when manipulating the contents of the orbit. This is a neurogenic reflex that can result in profound bradycardia and hypotension. It occurs when pressure is applied to the globe or when the extraocular muscles are stretched (notably during a forced duction test). When performing this test during surgery, always notify the anaesthetist.

Entire circumferential exposure of a defect in the orbital floor or walls can vary in difficulty, depending on a number of factors (size and site of defect, adherence of the infraorbital nerve to the periosteum, timing of repair, and the presence of swelling/bleeding). As a general rule, surgery is technically easier the sooner it is done, but this has to be balanced against other factors, such as swelling.

Whatever the choice of access, dissection within the orbit should always proceed in the subperiosteal plane. This can be difficult in the vicinity of the fractures, as the periosteum is often torn or shredded and the bones can be mobile. For this reason it is often helpful to start raising the periosteum at a site relatively remote (and therefore less injured) from the defect.

Some authorities recommend commencing the dissection along the lateral part of the floor of the orbit. This is because most blowout fractures involve the medial side of the floor. Of course this can be adjusted should the fracture pattern be different (*see* Fig. 9.69).

Appropriate instrumentation is important: a slightly sharpened elevator (or something similar) helps raise the subperiosteal layer cleanly and custom made retractors are also available (*see* Fig. 9.70).

Care is required with the infraorbital nerve. In some cases, the periosteum lifts off relatively easily, but in others, sharp dissection may be required to develop the plane between the nerve and periosteum.

A general approach to deep dissection is outlined in Table 9.5.

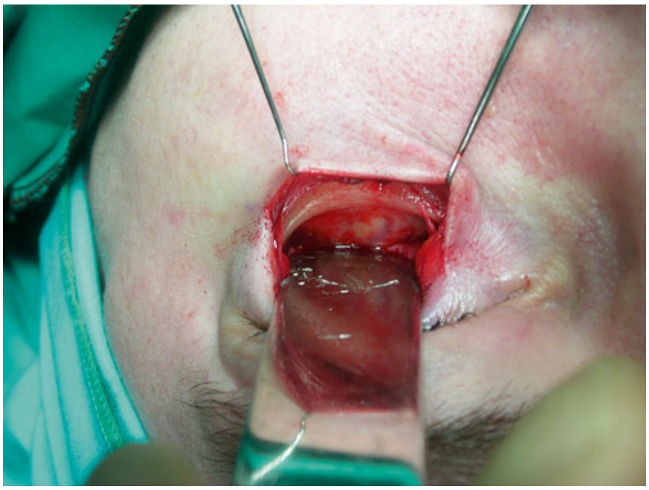


Fig. 9.69 Orbital dissection commences laterally, at a site remote from the fractures. Here subperiosteal dissection off robust bone is easiest

Fig. 9.70 Orbital retractor. This instrument is specifically designed to aid in the retraction of contents during exposure of the orbital floor

Table 9.5 Orbital exploration (a few tips and traps)

Know your anatomy (or have a skull in theatre)
Sagittal views on the CT scan will show how far back the defect goes (i.e., how close it is to the orbital apex)
Consider the use of steroids at the time of surgery and for a short period after
Use a headlamp and correct instruments
Inform the anesthetist when starting (reflex bradycardia)
Start laterally and dissect on a broad front
Contents passing though the inferior orbital fissure can be cauterised and divided—there are no important structures here. This will greatly improve access
The infraorbital nerve can have a variable relationship with the bone. Sometimes it needs to be carefully dissected free as the orbital contents are elevated
Define the periphery of the defect
A thick sheet of silastic makes a good retractor with large defects
An orbitotomy can improve access for "deep" defects
Implants often need to be secured
Do a forced duction test at the beginning and at the end (for comparison)
Don't panic if the pupil becomes dilated—this can be common. It is not a sign of blindness (know your cranial nerves)

Fig. 9.71 A suddenly dilated pupil is always a little worrying, but it is usually not a serious clinical problem. The commonest cause is traumatic mydriasis. Always check the pupil sizes and do a forced duction test before commencing surgery. Sometimes dilation may be pre-existing (if noted, get an ophthalmic opinion before surgery)

9.4.1.5 Deep Dissection

In principle, the aim of repair is to define the edges of the defect, return any herniated contents back into the orbit, and then cover the defect with a suitably strong material. The deepest edge of the defect (best seen on the sagittal views of the CT) is often called the "posterior ledge." With large defects this can be very close to the orbital apex. With small "trap-door" defects, repair is usually straightforward, the contents are reduced relatively easily, and the fracture realigns itself, often without the need for a graft (although some surgeons may prefer to place one anyway). Such defects can usually be accessed through a relatively small incision (*see* Figs. 9.72, 9.73, 9.74 and 9.75).

With larger defects, dissection and access becomes more difficult. If a transconjunctival approach has been used, adding a lateral canthotomy will certainly improve access considerably. This should always be considered with deeper or more complex defects. Transcutaneous approaches also provide excellent access but are becoming less popular due to the success and superior aesthetics of the transconjunctival approach. Division of the tissues passing through the inferior orbital fissure also greatly facilitates the lateral dissection along the orbital floor. If you are really struggling, an orbitotomy may help access to the deepest recesses of the orbit. This is described later.

The more one dissects, the more tissue there is to retract. Choice of instrumentation is important, although what feels best for one surgeon may not necessarily be best for another.

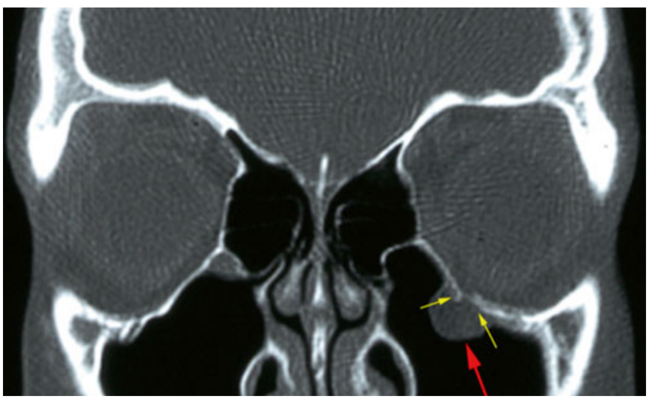


Fig. 9.72 A small trap-door defect. This can be approached through a relatively small incision. *Yellow arrows* indicate margins of fracture, *red arrow* indicate herniated orbital contents

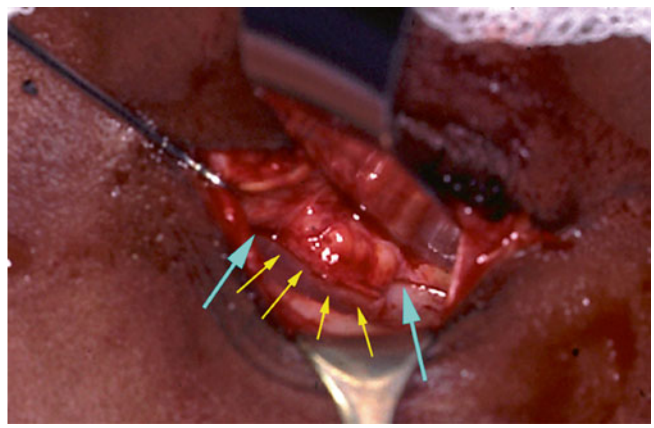


Fig. 9.73 Trap-door left orbit. The soft tissues (*yellow arrows*) are seen herniating through the defect (*blue arrows*). To reduce the contents, the hinged part of the trap door must be gently opened enough so that the contents can be gently teased back into the orbit. This must be done carefully; otherwise it may completely fracture, requiring a larger implant

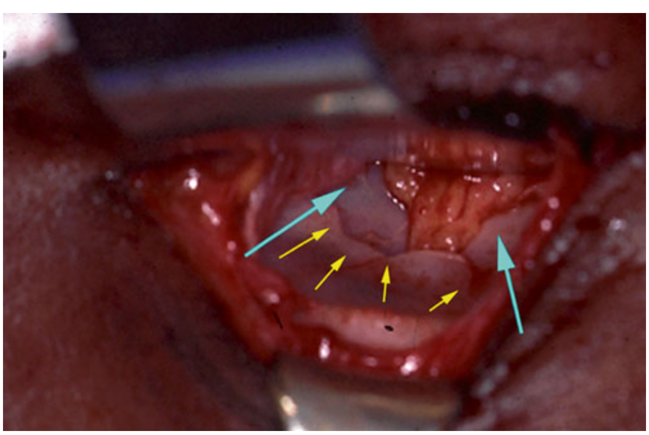


Fig. 9.74 As the contents reduce, the trap door becomes more obvious. Sometimes the fracture reduces completely, sometimes there is a small residual defect that may or may not need an implant. Small defects do not. *Yellow arrows* indicate margins of fracture, *light blue arrow* indicate trapdoor defect hingeing down

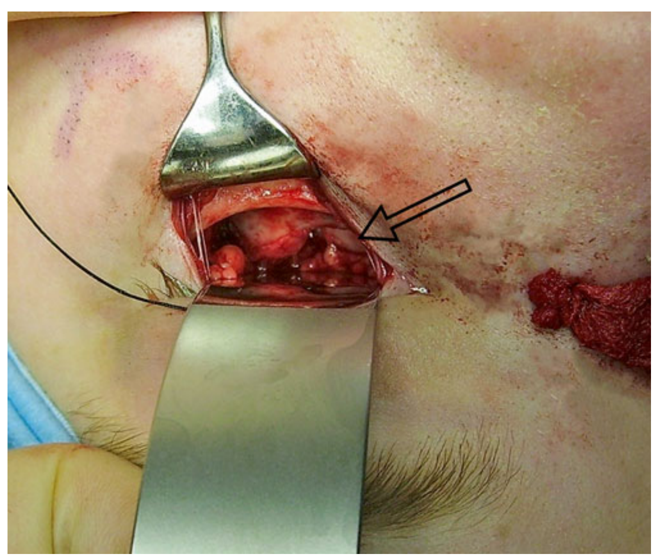


Fig. 9.75 The herniated contents can be seen returning to the orbit. The sooner surgery is done, the easier this is. With long delays (weeks) the contents become adherent and friable, making surgery technically harder

An element of trial and error is often required when learning this technique. Because the orbit narrows the further back you go, broad retractors cannot be placed deeply and sometimes a narrower one is a better choice. Good visualisation of the depths of the dissection is essential. Not only is it important to make sure you are not too deep (potentially damaging the optic nerve), but it is also important to ensure that the tissues at the back do not get trapped between the implant and the posterior ledge (on which the implant should sit). Similarly, when dissecting upwards along the medial wall (through an infraorbital approach), good retraction is essential to avoid trapping the soft tissues between the bone and the leading (upper) edge of the implant. Makeshift retractors can be surprisingly useful sometimes. A thick (2-mm) sheet of silastic cut to size can often help in difficult cases where the periosteum is shredded and fat keeps herniating into the field of view. Needless to say, good assistance and a headlamp will also make this a lot easier (*see* Figs. 9.76, 9.77 and 9.78).

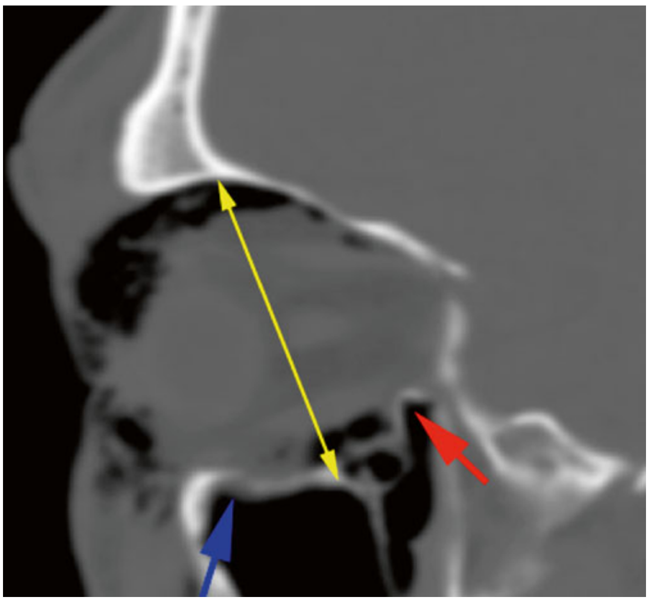


Fig. 9.76 Large defect seen on sagittal view. The defect starts at the *blue arrow* and extends to the *red arrow*—the posterior ledge. This needs to be completely spanned by the implant. Careful evaluation of the CT scan is important. Dissection at the back of the orbit will probably come close to the orbital apex. *Double yellow arrow* shows the increased orbital volume

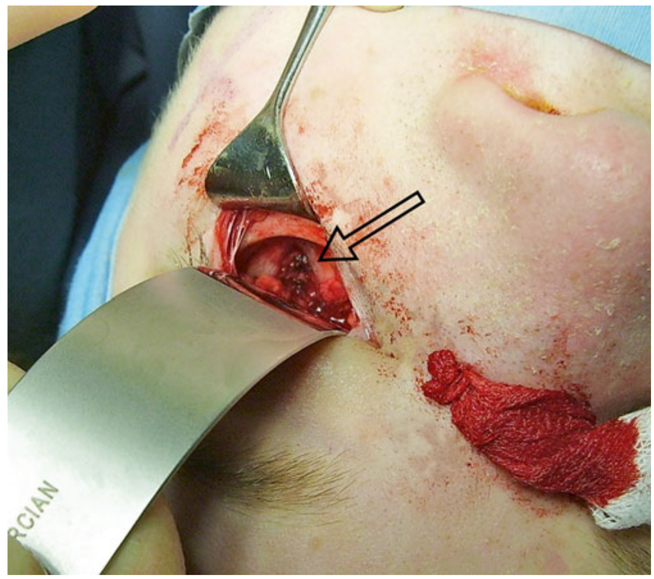


Fig. 9.77 The contents of the inferior orbital fissure can be safely divided. These often bleed, so bipolar cautery is best undertaken before division. Dividing these tissues will greatly facilitate retraction of the contents and exposure of the orbital floor. The fissure can now be seen

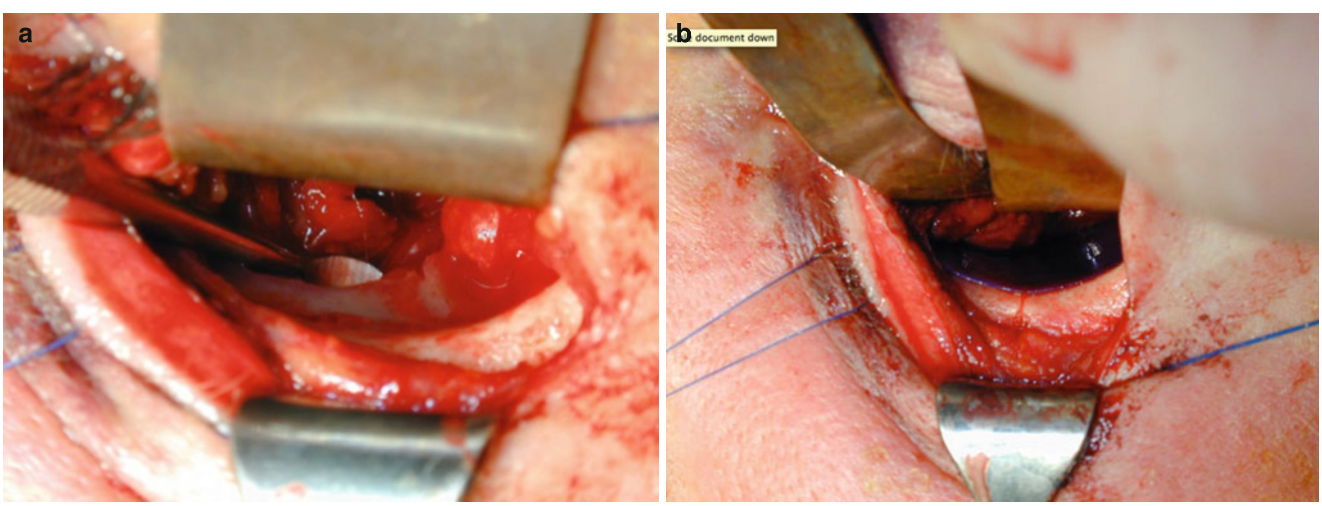


Fig. 9.78 Left orbital blowout (**a**, **b**). Once the orbital contents have been repaired, the graft/implant is placed over the entire defect

9.4.1.6 Repair of Defects

Once the orbital contents have been successfully reduced, they need to be supported to prevent them from re-herniating. Orbital defects can be repaired or reconstructed using a number of allogenic or autogenous materials. Ideally the material should be supported by the entire periphery of the defect, although this can sometimes be very difficult to achieve if the defect extends too close to the orbital apex.

Bone was once a very popular choice of material and many donor sites have been described in the literature. These include antral wall, cranium (calvarial), rib or iliac crest. Reports have also included cartilage, harvested from both the pinna and nasal septum. Being autogenous, the reported risks of infection and extrusion with bone and cartilage are very low, but they do require a second procedure to harvest the material. Alternatively, allogenic materials can be used. Today there are many different materials available, including titanium sheets, mesh, polymers and newer resorbable materials. Each has its own advantages and disadvantages compared to the others and the final choice is often largely one of personal preference and cost. Titanium is currently a popular choice. A small selection of materials available is shown (*see* Figs. 9.79–9.87).

Fig. 9.79 Iliac crest bone (**a**) used to repair a right orbital floor defect (**b**)

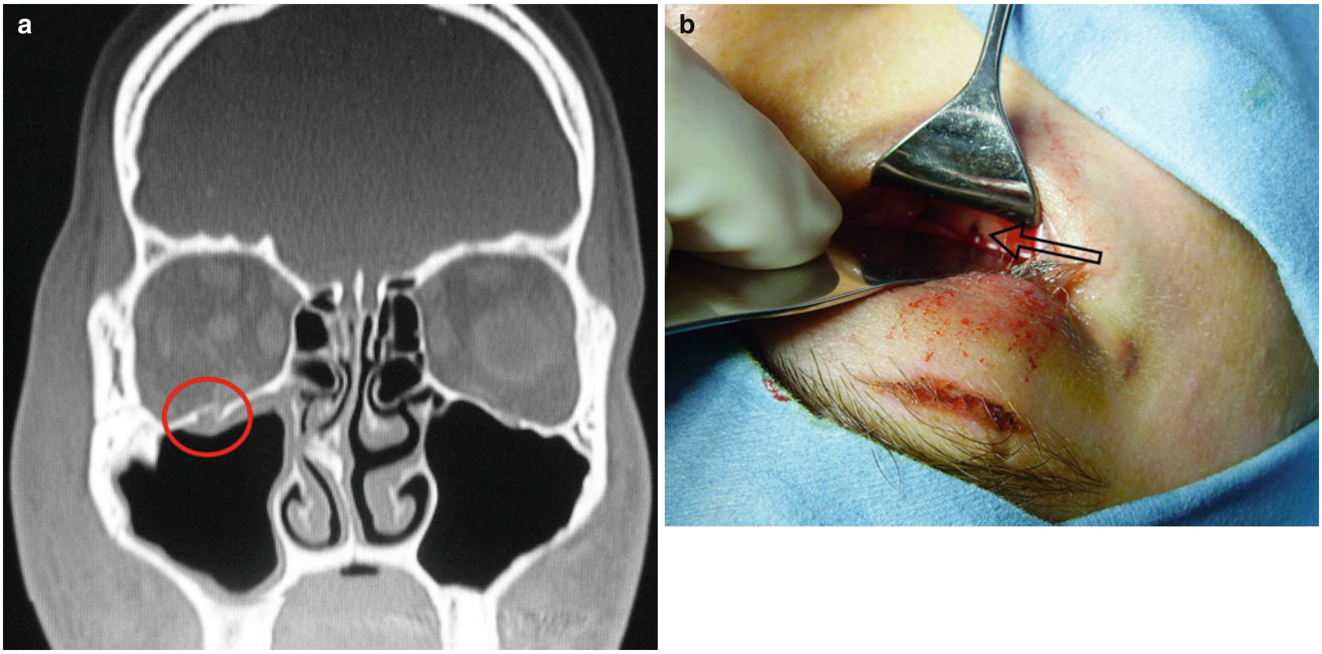


Fig. 9.80 Although mostly superseded by titanium, silastic still has a useful role in the management of small trap-door defects (**a**). The defect is shown following release of the trapped tissues (**b**). *Red circle* represents the fractured orbital floor

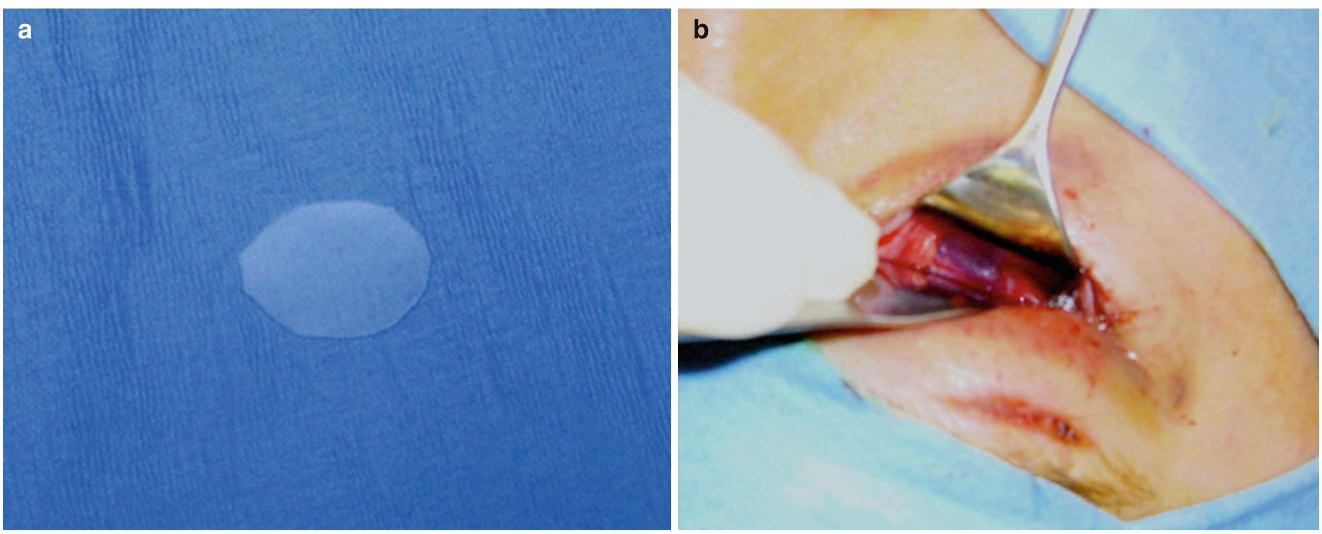


Fig. 9.81 A thin sheet of silastic is then cut to shape (**a**) (here it is approximately 1 cm in diameter). This is used to cover the defect (**b**). Silastic has very little intrinsic strength and therefore offers no structural support. Its role here is simply to prevent the soft tissues from catching on the bone edges. The bones themselves are still supporting the orbital contents

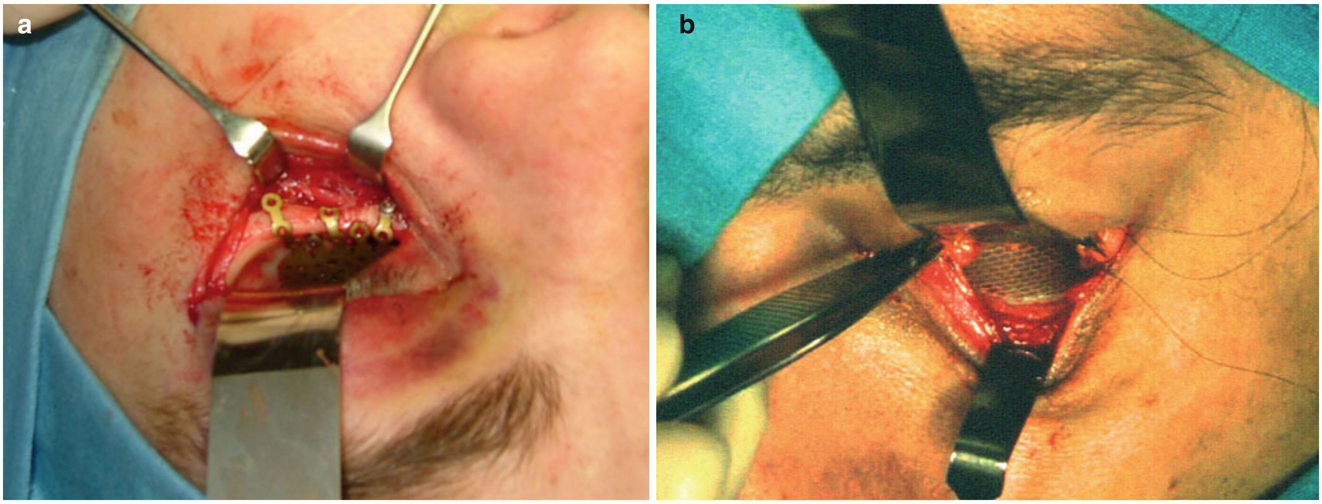


Fig. 9.82 Titanium has gained popularity in the repair of orbital defects (**a**, **b**). It is generally inert and much more rigid than silastic. This comes in many forms (sheets, mesh). Thin titanium mesh also can be coated with a thin layer of silastic (reinforced silastic)

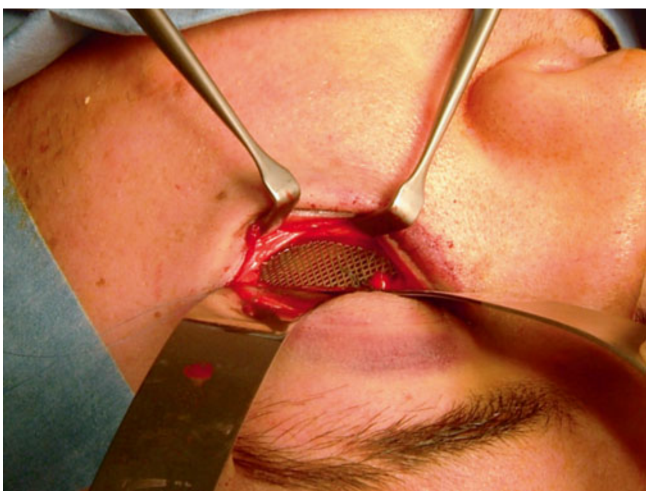


Fig. 9.83 Titanium mesh

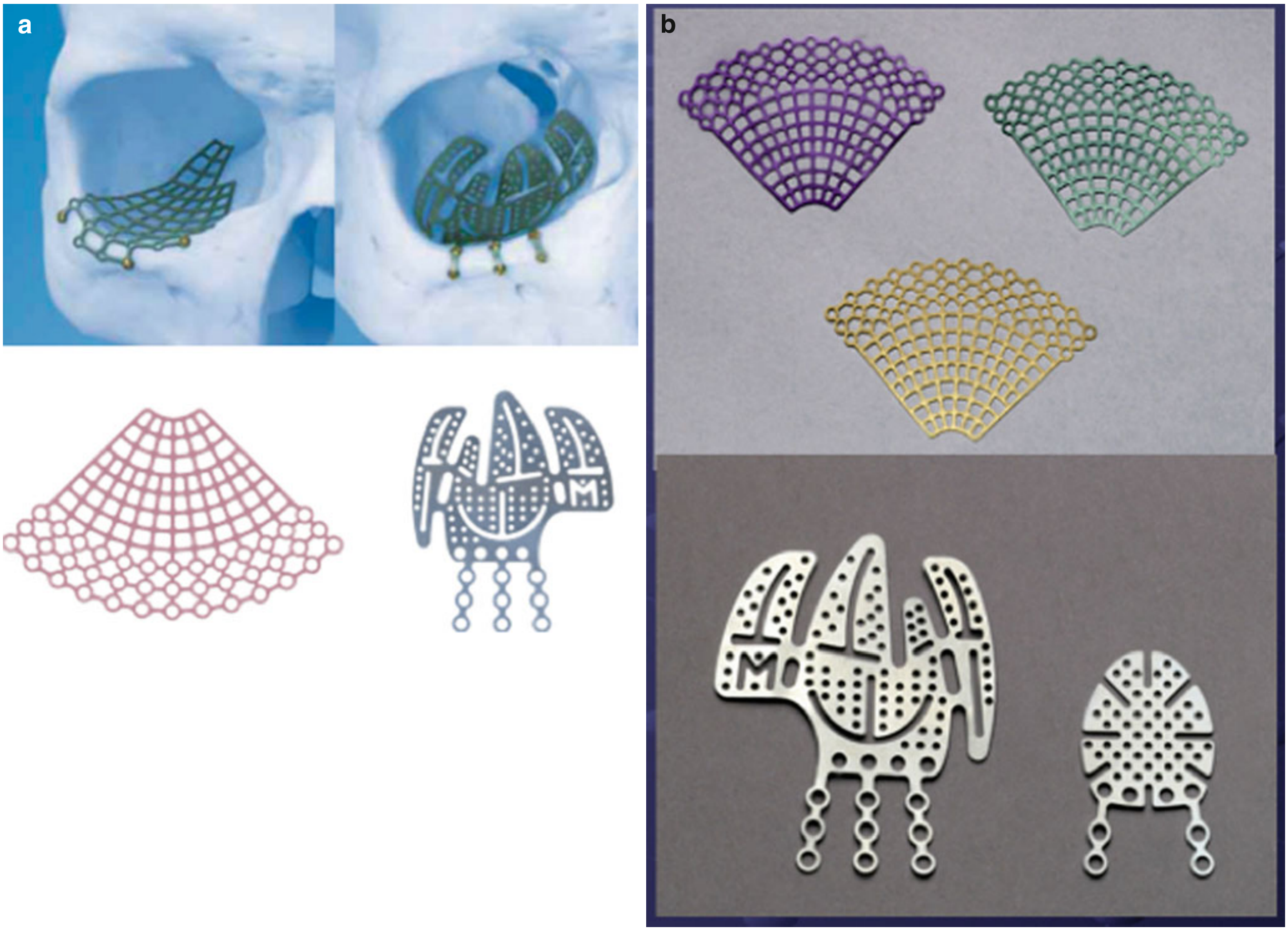


Fig. 9.84 Various configurations of titanium sheets exist. These are designed to reconstitute orbital anatomy (**a**, **b**)

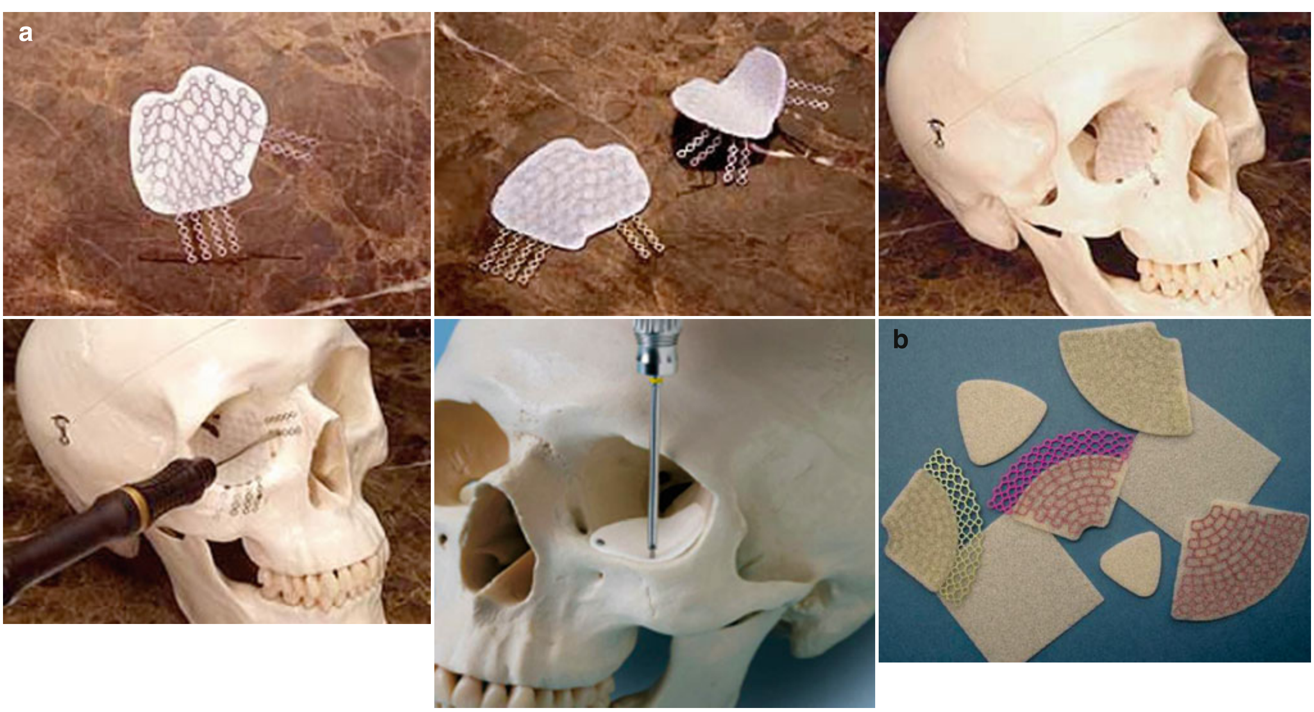


Fig. 9.85 Medpor (high-density porous polyethylene) is another material commonly used. It is reported to integrate with the soft tissues, reducing the incidence of infection (**a**, **b**)

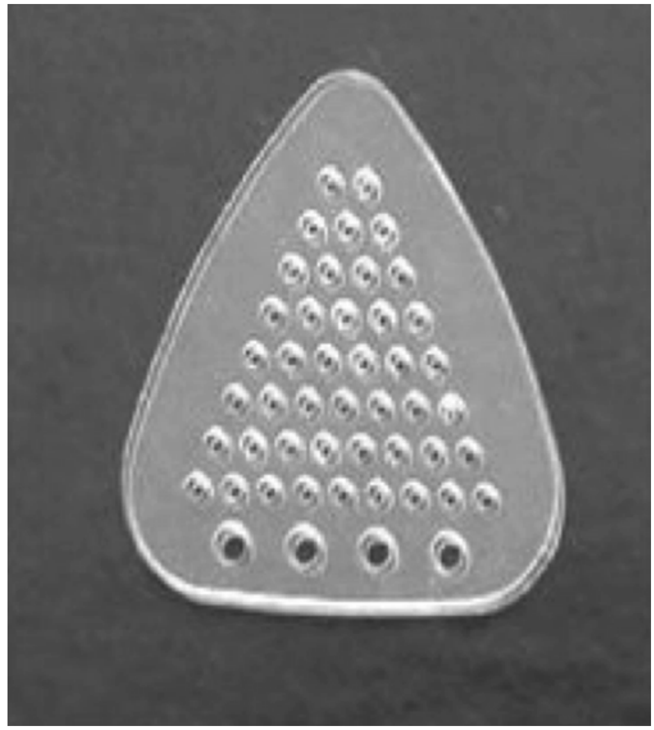


Fig. 9.86 Resorbable materials are also available

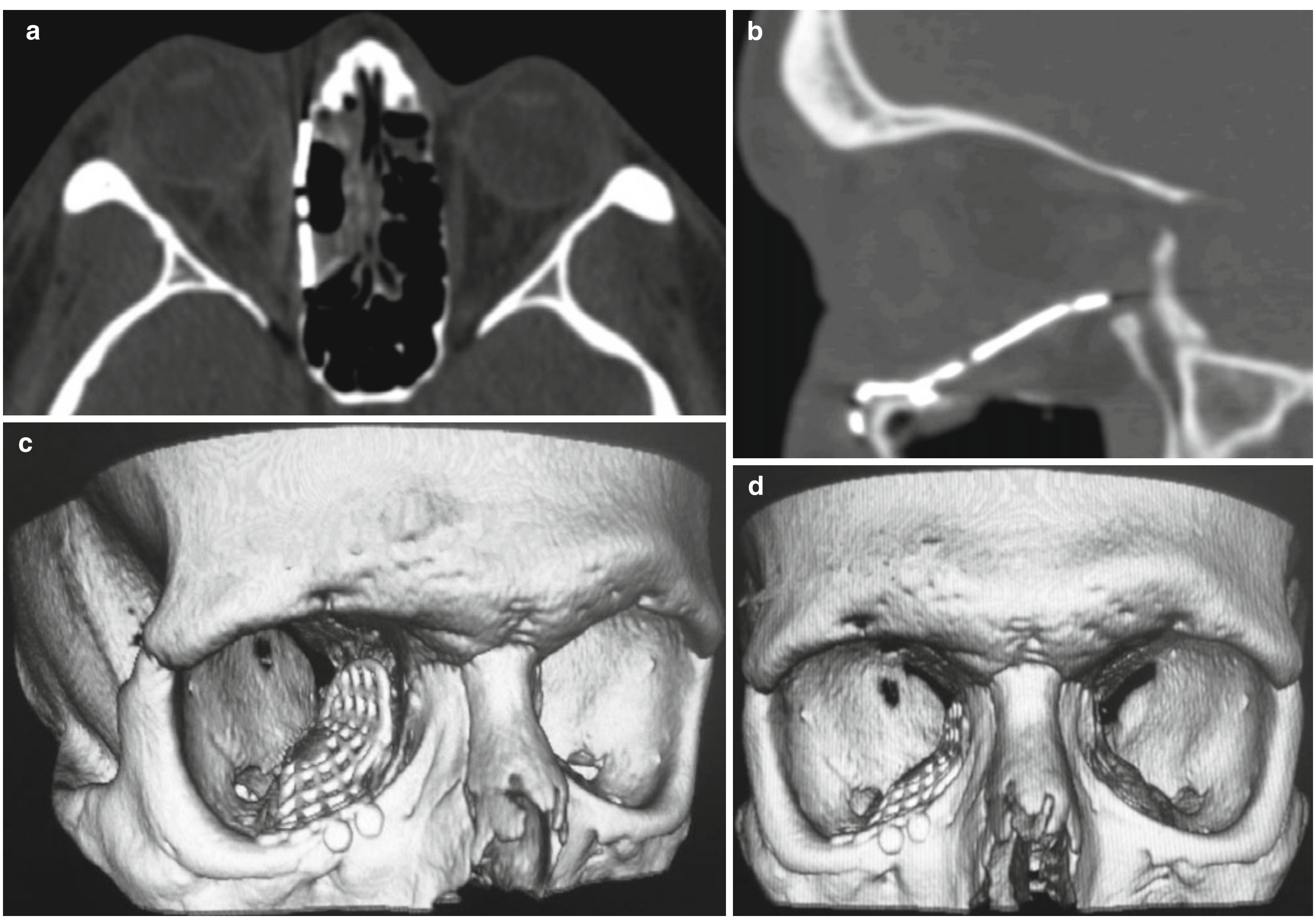


Fig. 9.87 Repair using titanium has the advantage of allowing critical evaluation on postoperative scans (**a**–**d**)

Whatever the choice of material, the aim is to accurately restore the shape (and hence the volume) of the orbit. This can be difficult, especially when two or more walls are fractured (most commonly the floor and medial wall). Although it may be possible to completely reduce the orbital contents and span the entire defect, the complex curvatures of the orbital walls means that a flat sheet of material may not necessarily restore the shape. The commonest site where this problem occurs is at the posteromedial bulge (*see* Fig. 9.88).

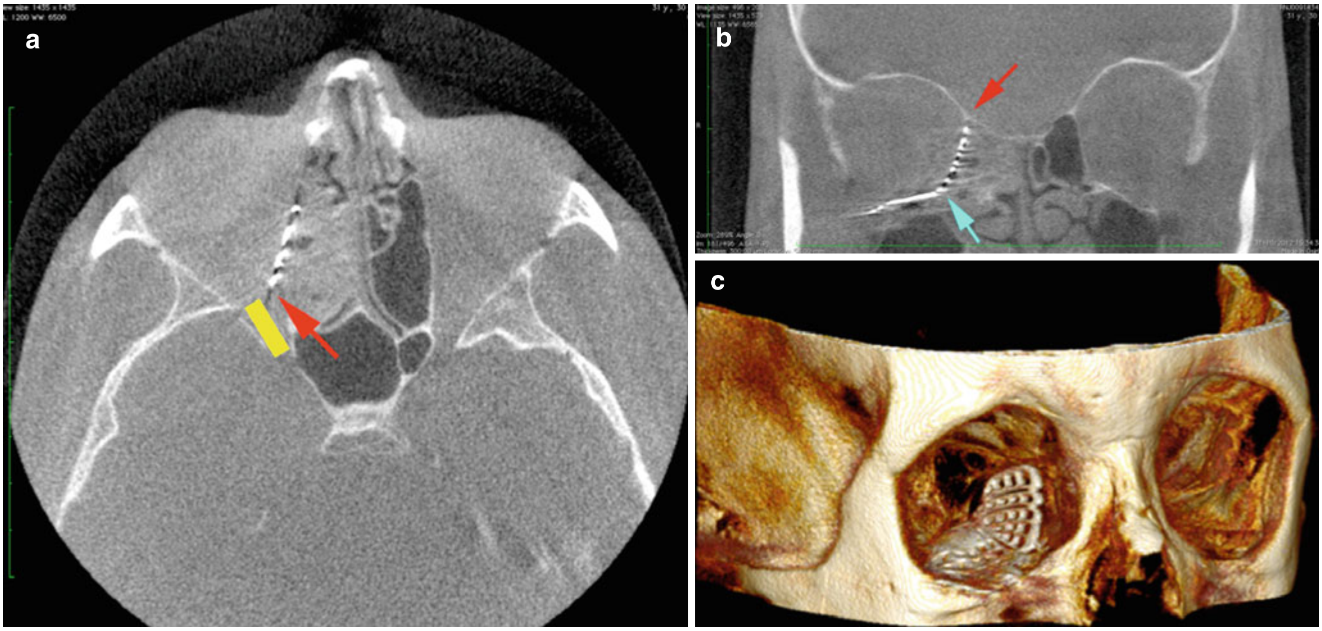


Fig. 9.88 Repair of two-wall defect with titanium (**a**–**c**). Difficult aspects in repair are precise placement of the implant in the deepest recesses of the dissection (*red arrows*) and in reproducing the posteromedial bulge (*blue arrow*). *Yellow rectangle* represents the optic nerve

Precontoured (preformed) titanium plates are now available for the repair of floor and medial wall defects. These are designed to reproduce the orbital contours at these sites. Unfortunately, this means greater precision is required when placing these plates as there is considerably less room for error compared with flat sheets. Ideally, navigational surgery should be available for this, but in reality not all centres can afford this expensive equipment. Endoscopic-assisted surgery is another, slightly less costly method to help improve precision (*see* Figs. 9.89–9.97).

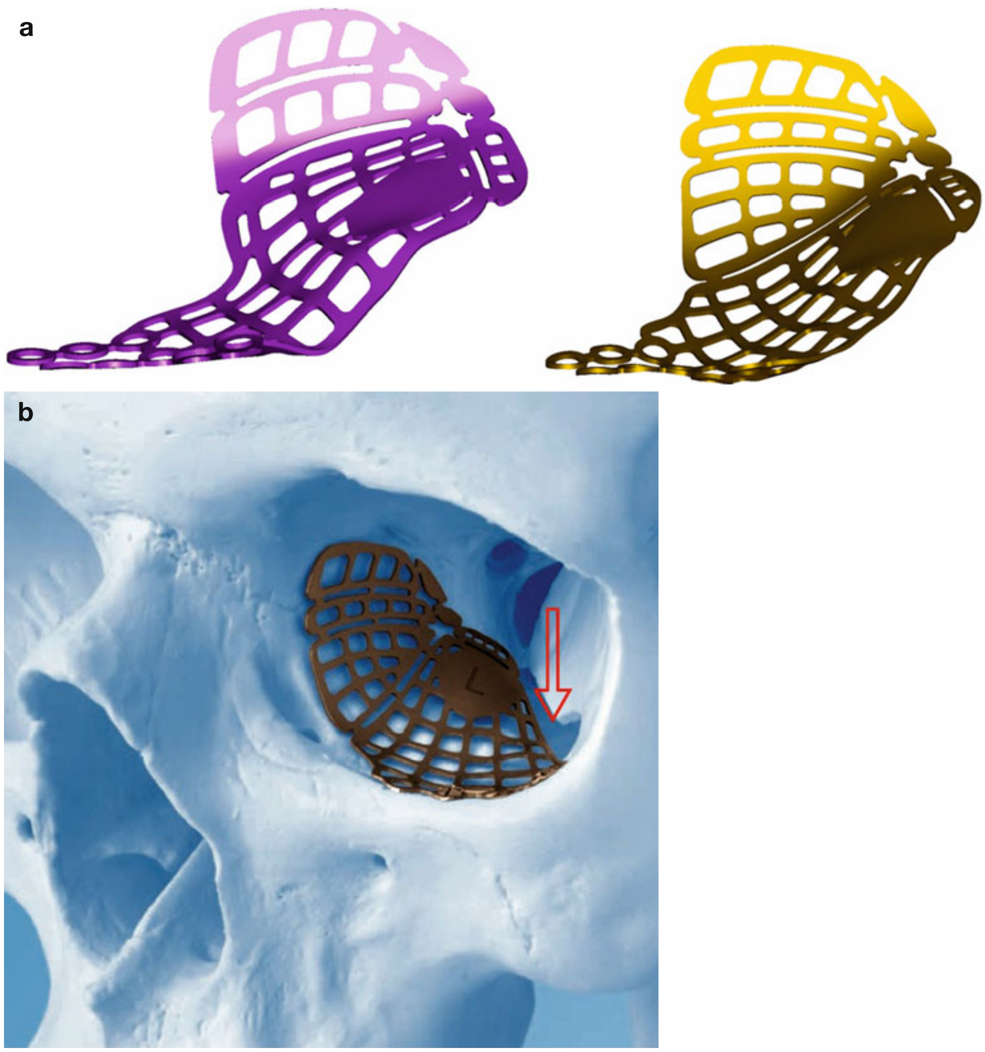


Fig. 9.89 Precontoured (preformed) orbital plates are designed to reproduce the complex geometry of the orbital floor and medial wall. They come in two sizes (small and large) (**a**, **b**)

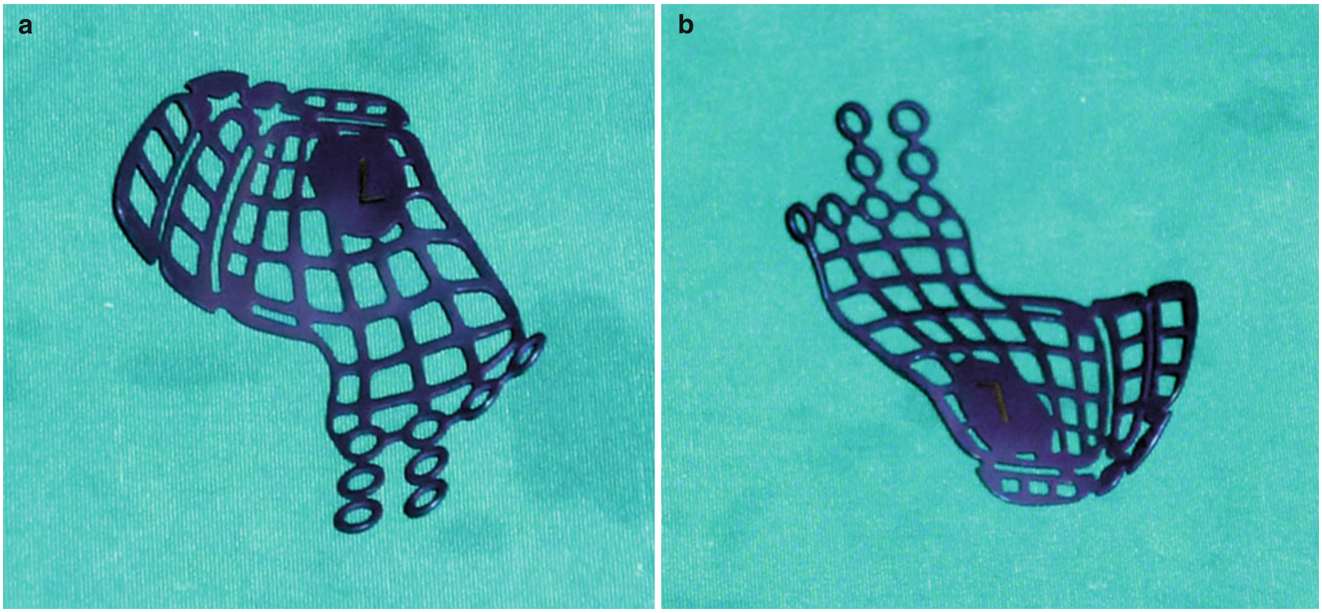


Fig. 9.90 Preformed orbital plate (**a**, **b**)

Fig. 9.91 These can be very difficult to place accurately, but currently offer the best chance of restoring orbital geometry. They are placed in a specific manner with the medial wall as the leading edge. Good access, lighting, and assistance is essential with large defects

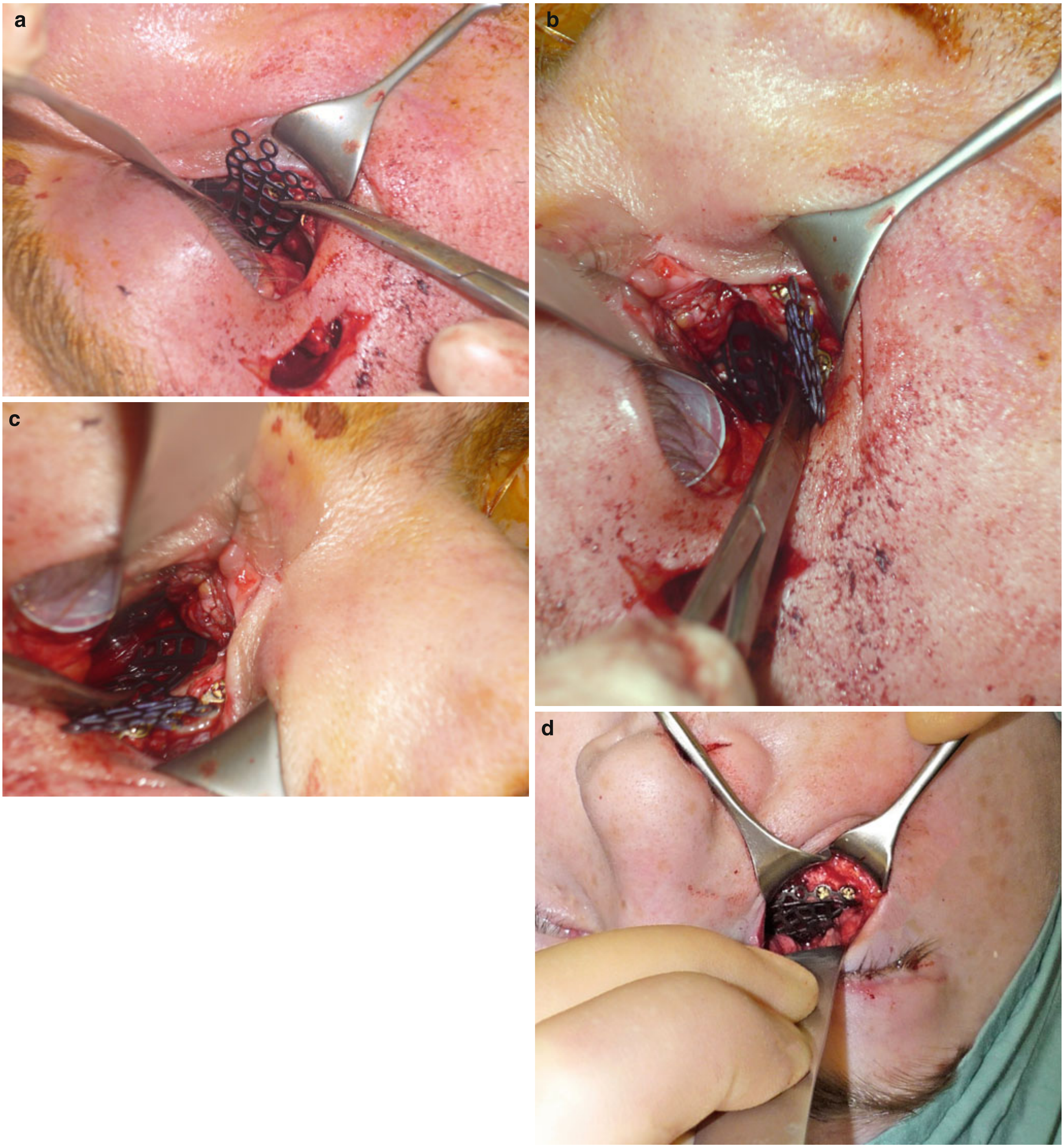


Fig. 9.92 Viewed from different directions (**a**–**d**). The implant is secured to the infraorbital rim. When positioned accurately it will reconstruct the sloping surfaces of the orbital floor and posteromedial bulge

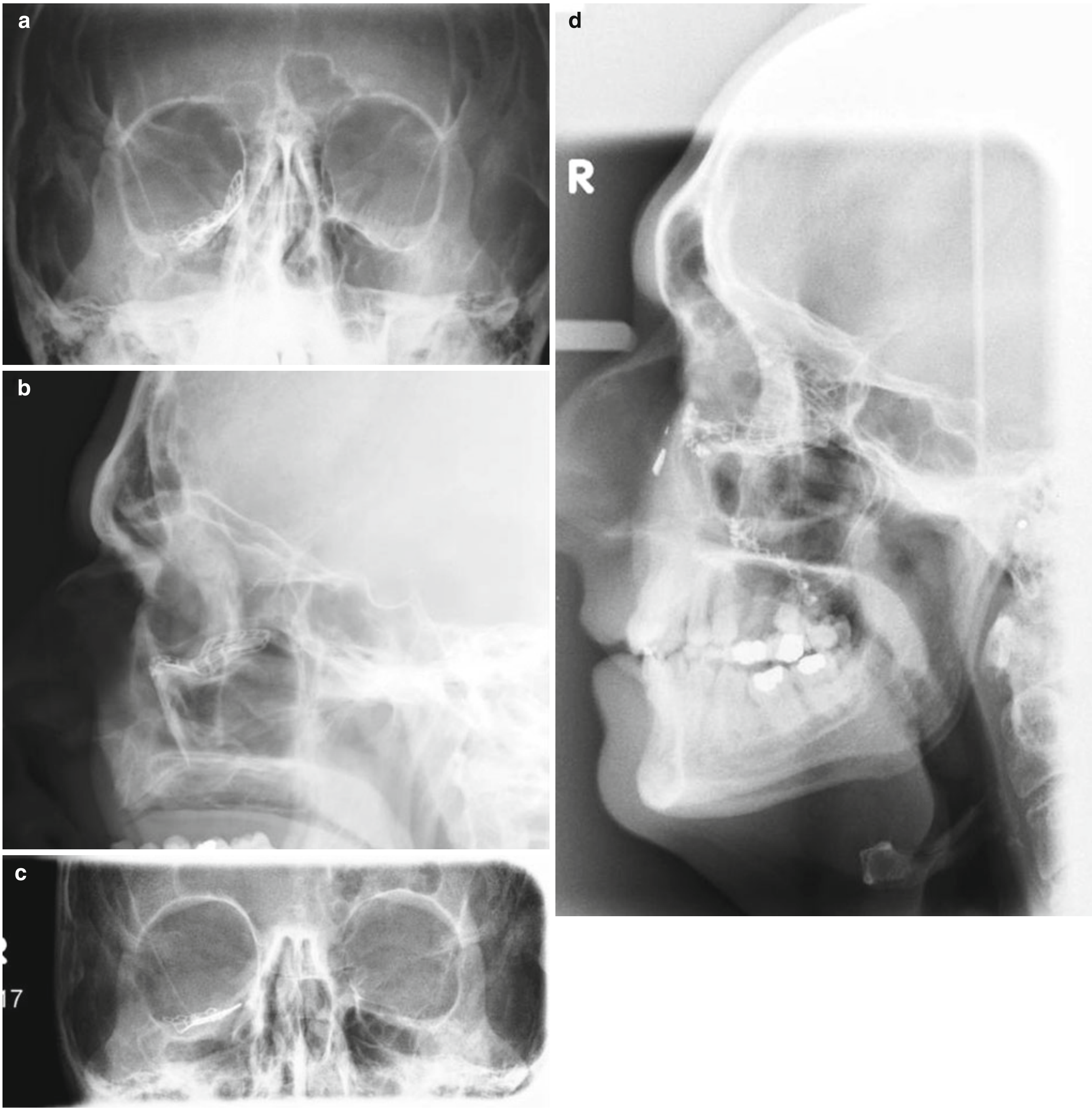


Fig. 9.93 (**a–d**) Postoperative imaging is recommended with these plates. Precise placement is very technique sensitive. In these cases, plain films have been taken

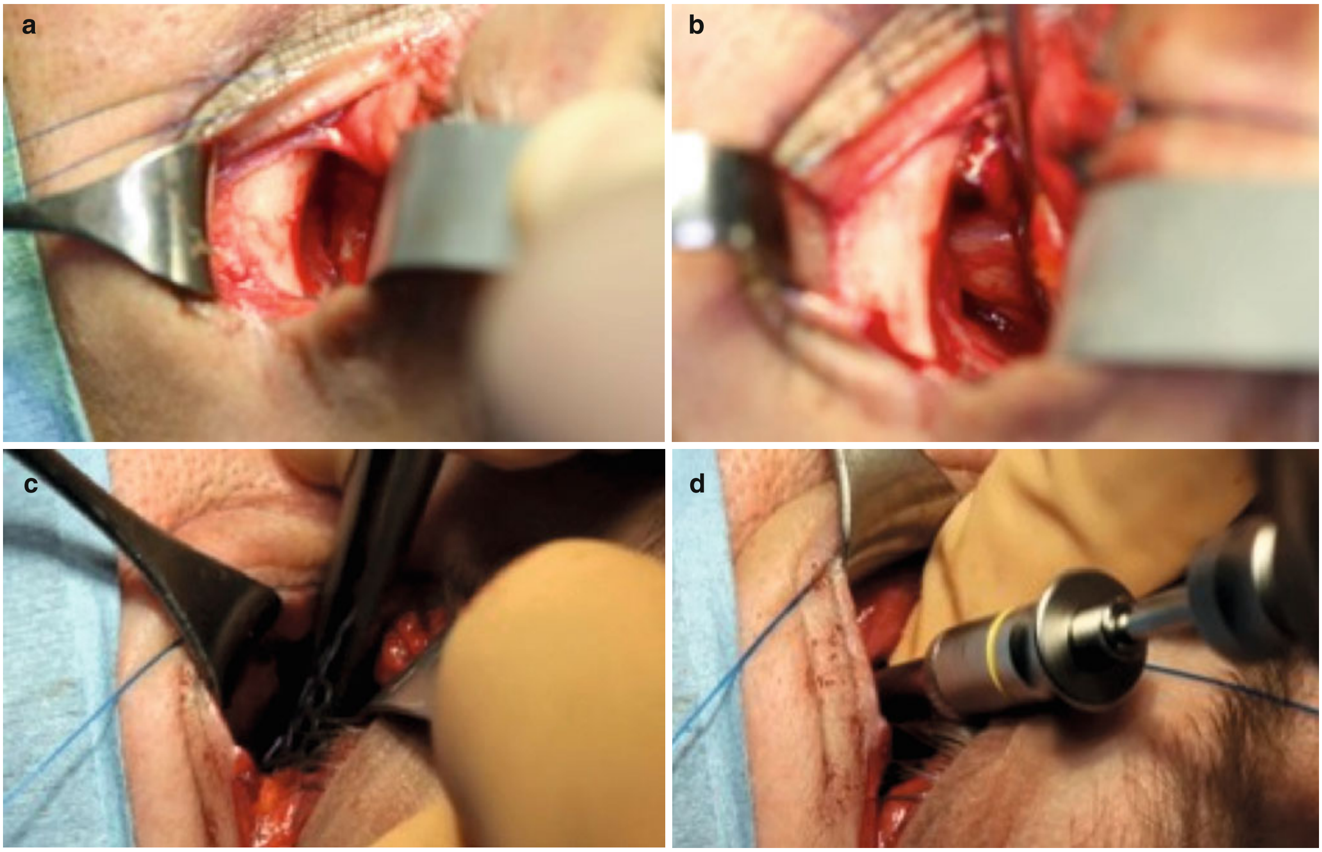


Fig. 9.94 Left orbital blowout repair with preformed titanium (**a**–**d**) (*see* text and previous case)

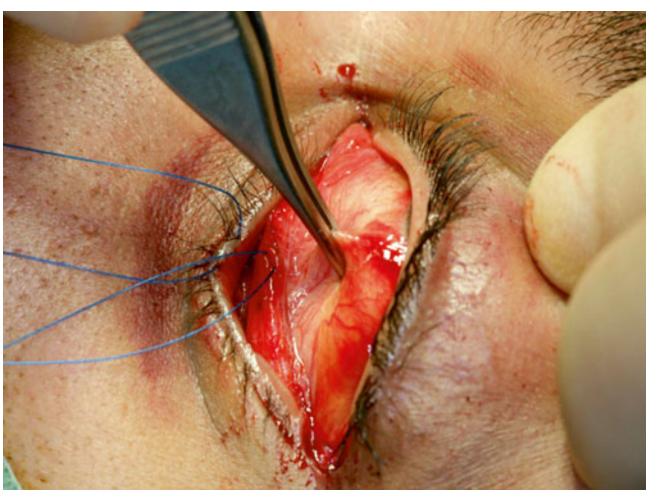


Fig. 9.95 Remember to do a forced duction test at the end of the procedure. A poorly positioned plate can trap tissues, both inferiorly and medially

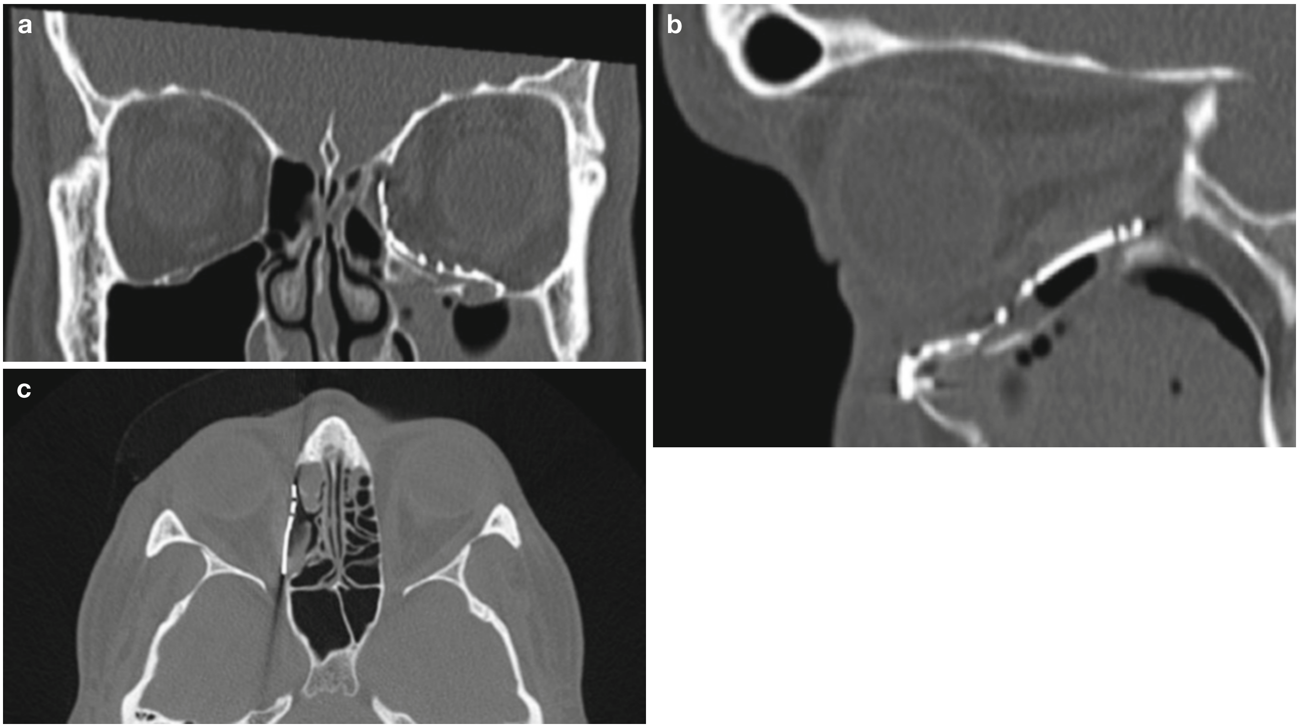


Fig. 9.96 Postoperative CT showing satisfactory plate position (**a**–**c**)

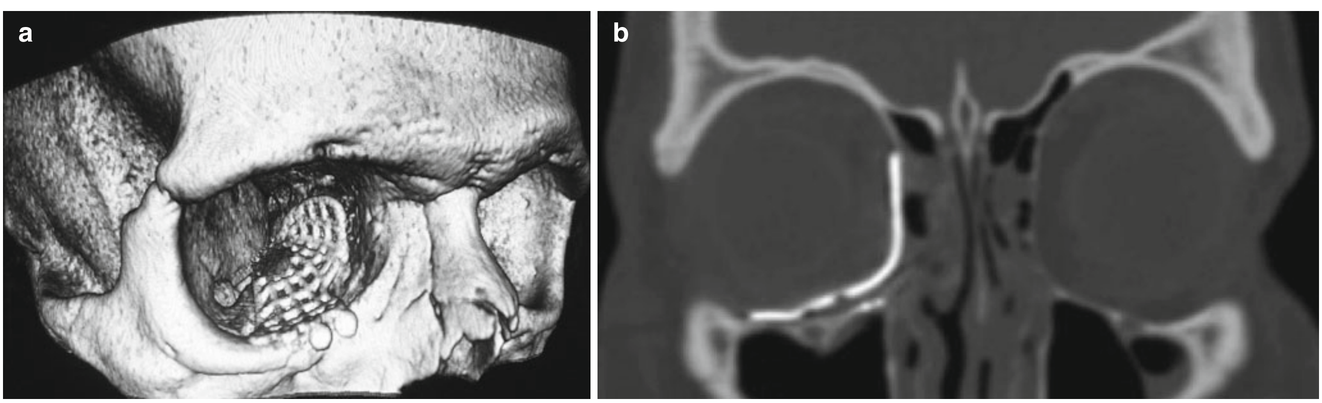


Fig. 9.97 Further examples (**a**, **b**)

9.4.2 Medial Orbital Fractures

Fractures of the medial orbital wall can occur in isolation, or as a medial extension of orbital floor defects. Isolated fractures are common. These can either be "blowout" or "blow-in" in nature. In the latter case, the mobile fragment is displaced into the orbit (as opposed to the ethmoid sinuses), resulting in proptosis and ocular dystopia. For a number of reasons, these are a difficult group of fractures to repair—access is somewhat limited and deep dissection along the medial orbital wall comes into very close contact with the orbital apex. Significant bleeding can also occur due to the proximity of the ethmoidal vessels (*see* Figs. 9.98, 9.99, 9.100 and 9.101).

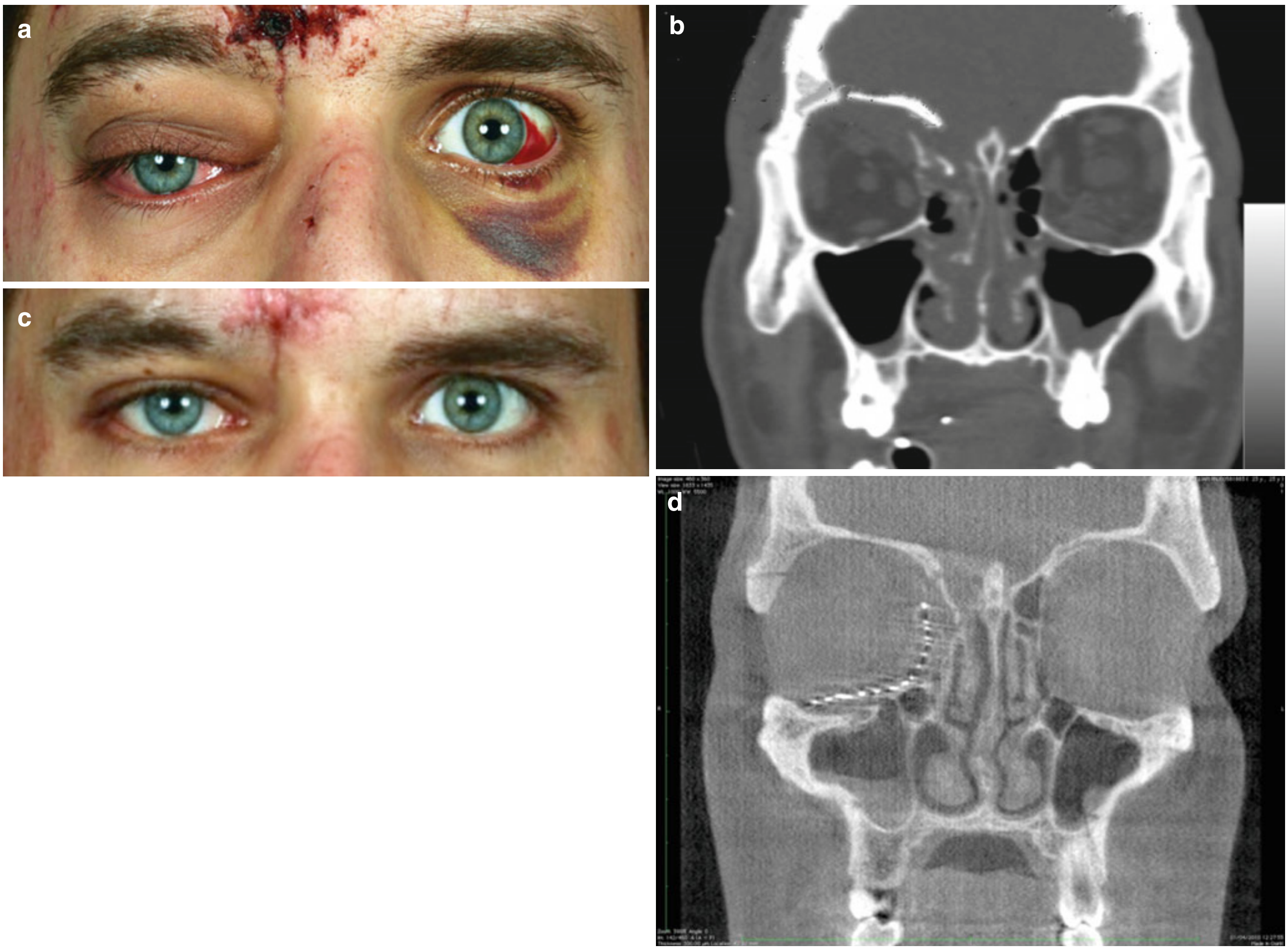


Fig. 9.98 Medial wall "blow-in" fracture with proptosis and ocular dystopia. Preoperative (**a, b**). Post operative (**c**, **d**)

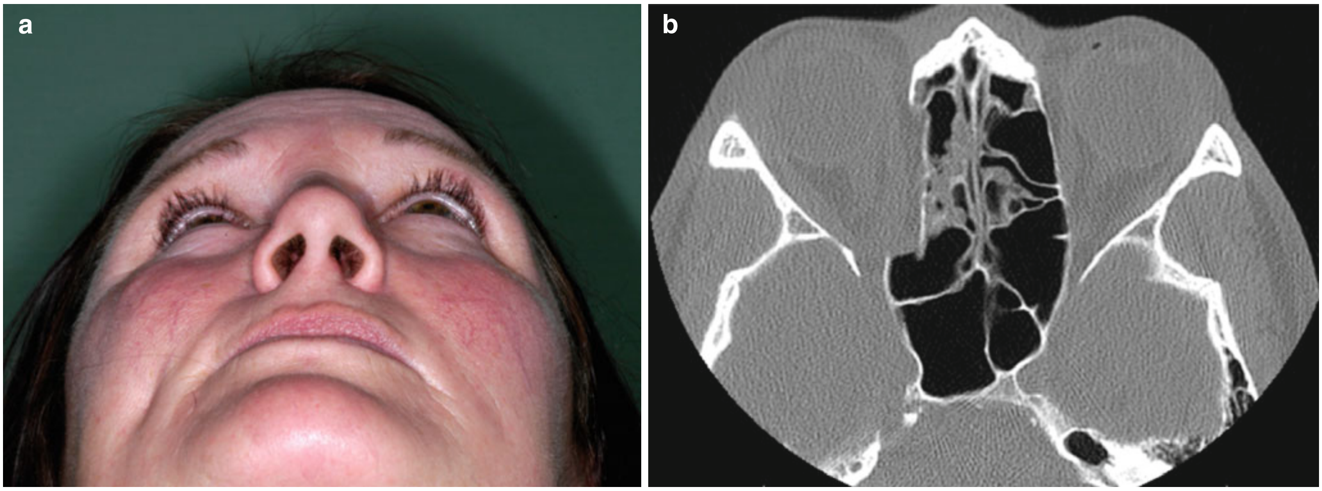


Fig. 9.99 Isolated medial wall blowout fracture (**a**, **b**)

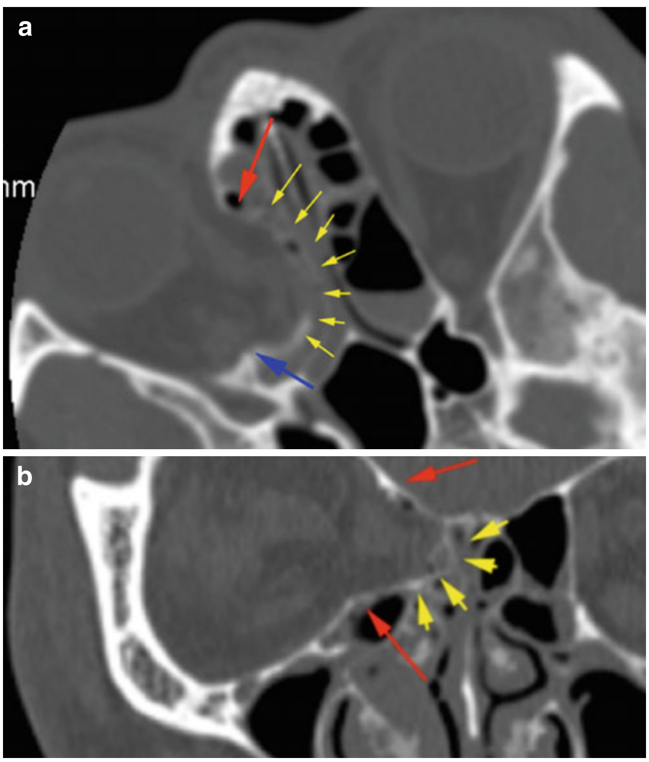


Fig. 9.100 Extensive medial wall blowout fracture with gross herniation of tissues (**a**–**b**). *Red arrows* indicate margins of fracture, *yellow arrows* extent of displacement of the lamina papyracea, *blue arrows* indicate posterior margin of fracture next to optic canal

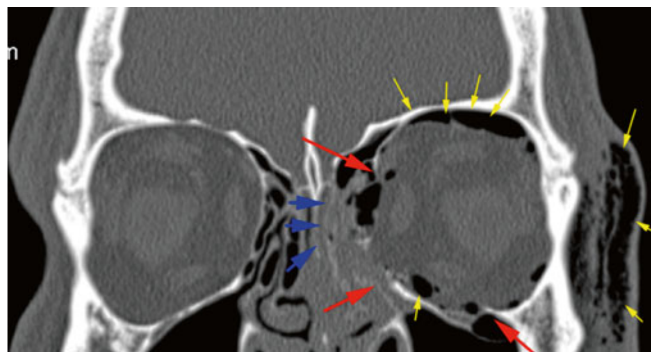


Fig. 9.101 Complex injury involving medial wall and floor of orbit. There is significant emphysema from nose blowing (*yellow arrows*). Note depth of posterior limit and its relationship with the orbital apex

9.4.2.1 Surgical Repair

Access to the medial orbital wall is possible through a number of approaches. It may be possible to access the lower half of the wall through any of the infraorbital approaches previously described. However, this is somewhat limited and clear visualisation of the entire wall can be very difficult. The coronal flap is reported to provide good access to the upper half of the medial wall, but may be an excessive approach for isolated defects. More direct access is possible transcutaneously, or through a "transcaruncular" approach.

Transcutaneous Approach to the Medial Wall

The transcutaneous approach requires a suitably sized skin incision placed alongside the medial canthus. A zig-zag design minimises unsightly scarring. Through this incision, the underlying periosteum is incised and subperiosteal dissection along the medial wall undertaken. The obvious limitation here is the attachment of the medial canthus, which restricts access and prevents passage of any sizeable implant. Nevertheless, combined with an infraorbital approach, this incision is relatively easy to do, facilitating exposure of the upper part of the defect and manipulation of the leading edge of any implant. The canthus should not be detached. These incisions generally heal well with acceptable scarring (*see* Figs. 9.102, 9.103 and 9.104).

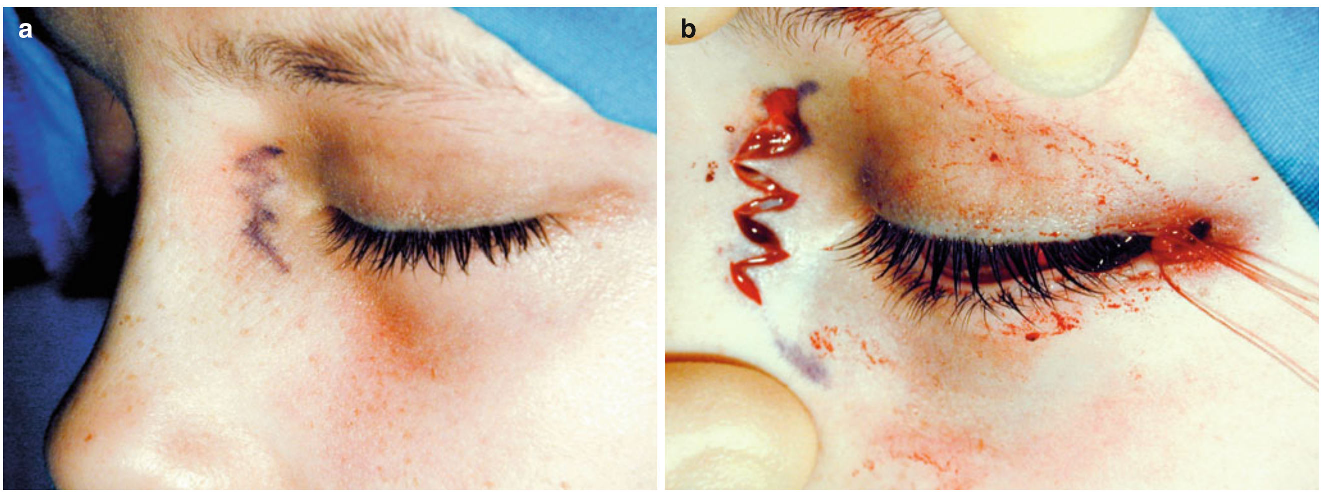


Fig. 9.102 This approach has been combined with a transconjunctival approach to the orbital floor. A zig-zag design minimises scar contraction (**a**, **b**)

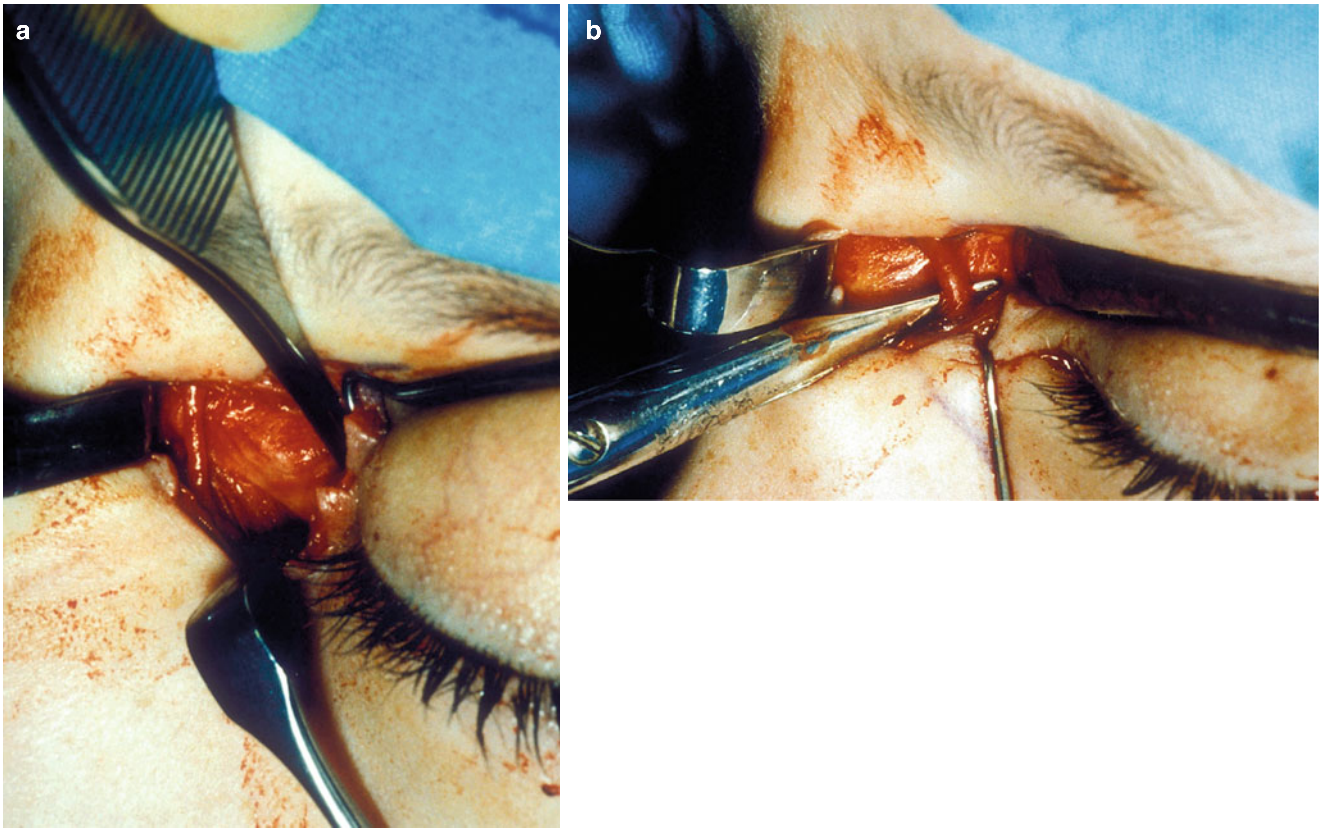


Fig. 9.103 Initial dissection identifies the medial canthal attachment. This is left undisturbed. The external angular vein is shown prior to division (**a**, **b**)

Fig. 9.104 Although limited, this does allow access and visualisation of the medial wall and leading edge of the titanium plate. Repair is not possible through this approach alone. The wound is closed in layers

Transcaruncular Approach

More recently the transcaruncular approach has gained increasing popularity. In a sense, this can be thought of as a medial transconjunctival approach, with elements similar to the retroseptal dissection. Following incision of the conjunctiva, blunt dissection (using tenotomy scissors) is progressed behind the medial canthal attachment onto the posterior lacrimal crest on the medial wall. It is here that the periosteum is then incised and elevated, leaving the medial canthus and lacrimal sac undisturbed. Through this incision the periosteum can be widely elevated exposing most of the medial wall as far back as the orbital apex (although such an extensive exposure is not recommended routinely). The anterior and posterior ethmoid foramina lie along the medial wall, through which the anterior and posterior ethmoid arteries pass. These are important surgical landmarks, marking the level of the cribriform plate and the anterior cranial fossa. Grafts may or may not need securing, depending on how they lay passively. If a graft is secured with a screw anteriorly, make sure it does not "kick out" at the back (into the orbit) as the screw is tightened. Following repair, sutures are often not required for closure (*see* Figs. 9.105, 9.106, 9.107 and 9.108).

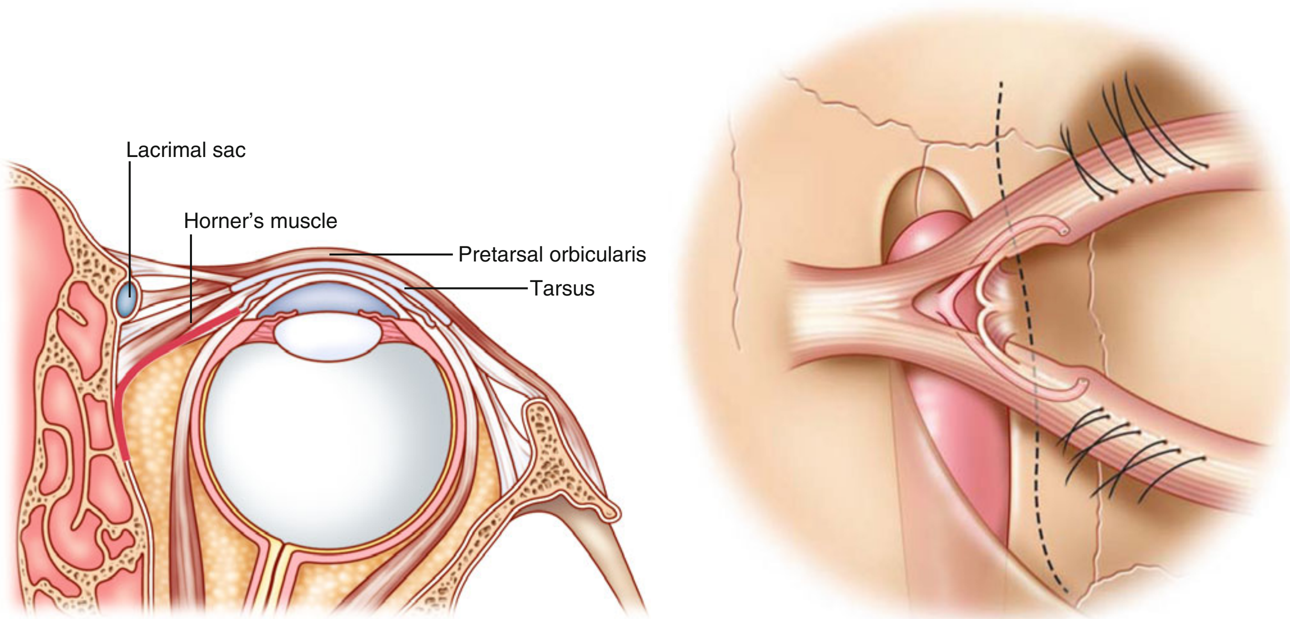


Fig. 9.105 The transcaruncular incision is shown here. Passing through the conjunctiva, the dissection proceeds deep to the lacrimal apparatus and medial canthal attachment. The periosteum is incised behind the posterior lacrimal crest

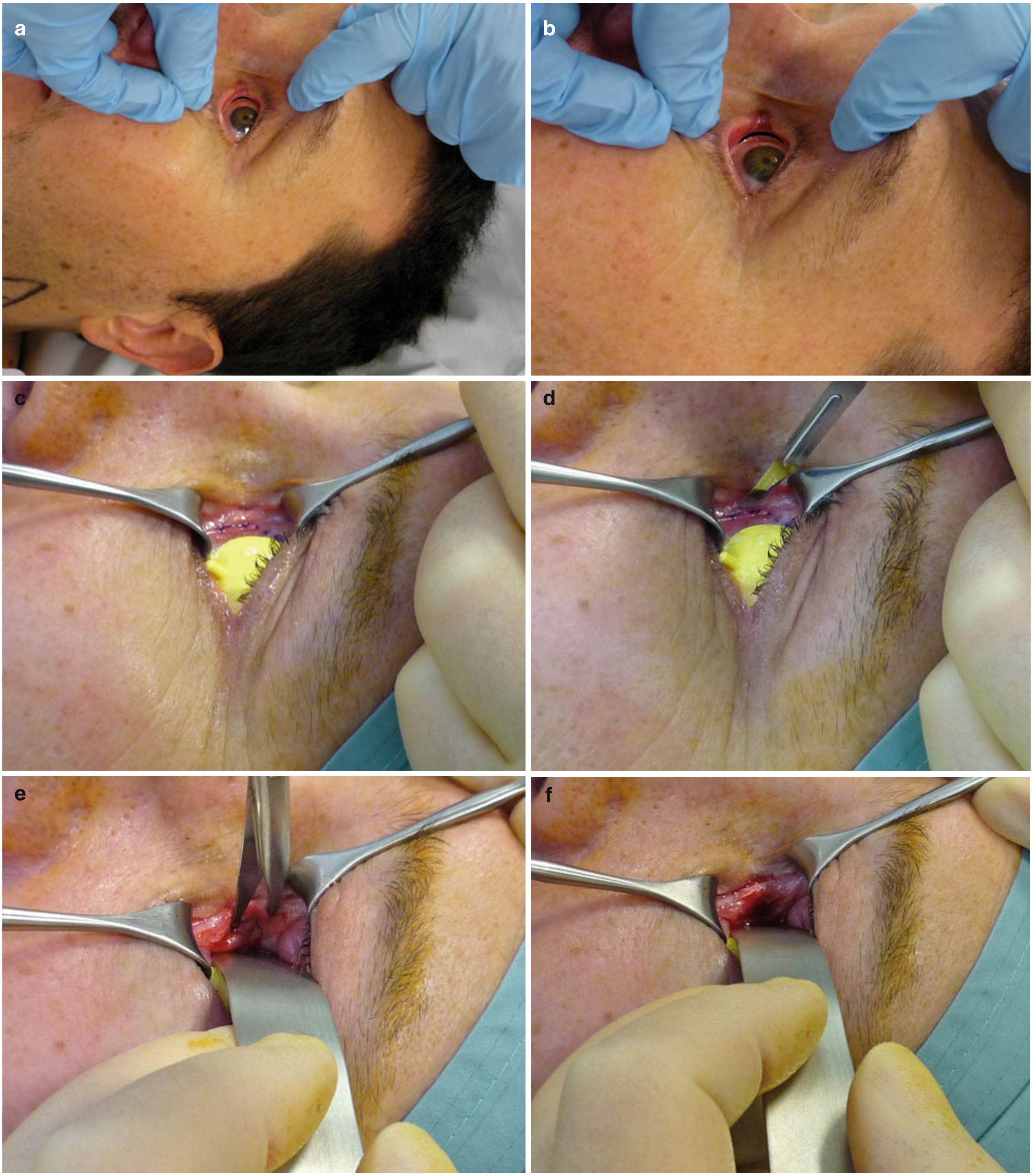


Fig. 9.106 Transcaruncular approach. Think of this as a medial transconjunctival approach. The line of incision is shown (**a**, **b**). The incision is marked and the conjunctiva incised (**c**, **d**). Tenotomy scissors develop the plane, heading toward the bone, posterior to the posterior lacrimal crest (**e**, **f**). The plane of dissection is shown in (**g**). Once the periosteum is reached (*arrow* in **h**), it is incised along the length of the wound (**i**). The periosteum is then elevated, working on a broad front (**j**, **k**). Starting on firm bone, the periosteum is gradually elevated to define the periphery of the defect. Care is required with deep defects. Deep dissection here will come onto the orbital apex (**l**). Therefore check your scans preoperatively (**m**)

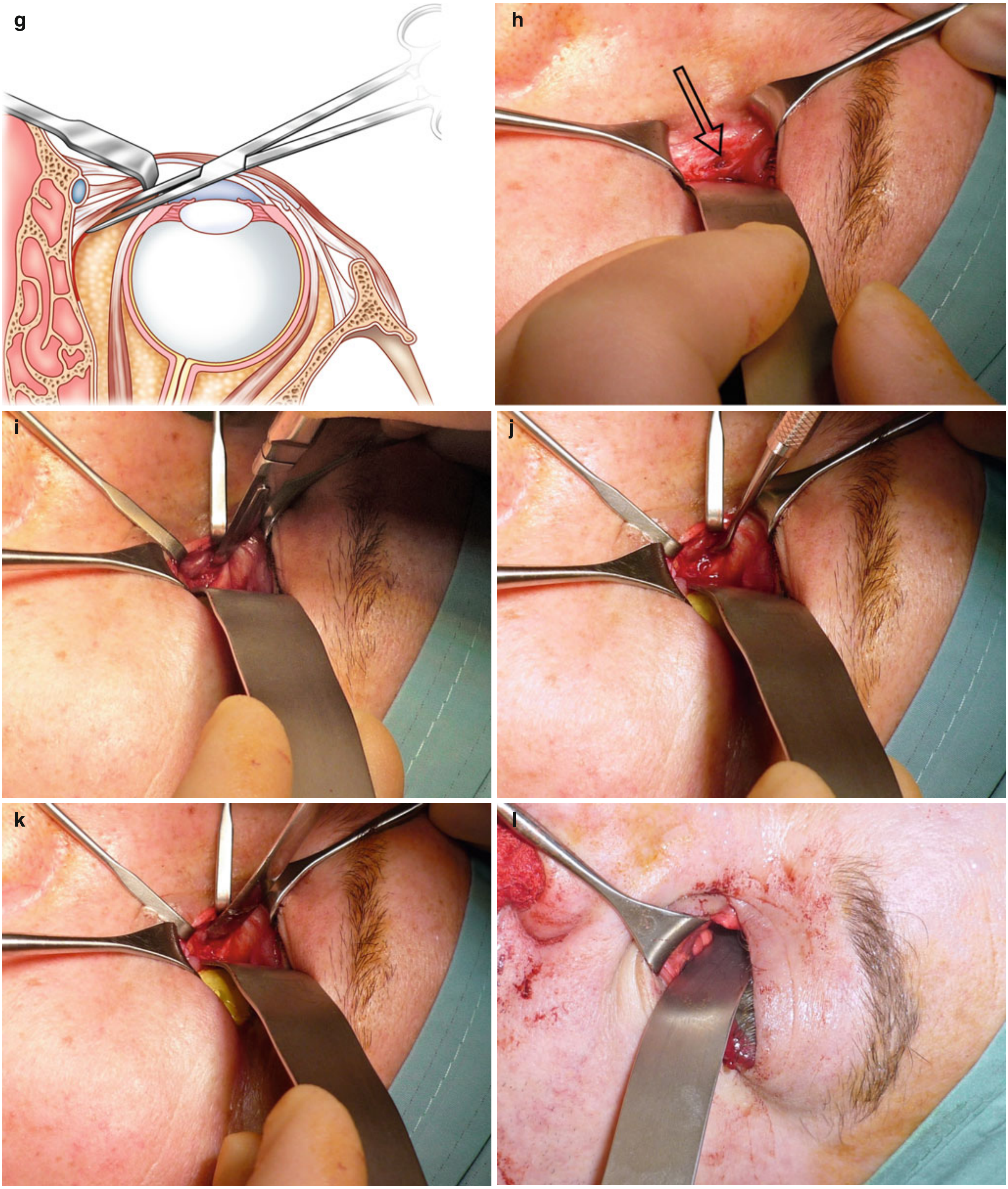


Fig. 9.106 (continued)

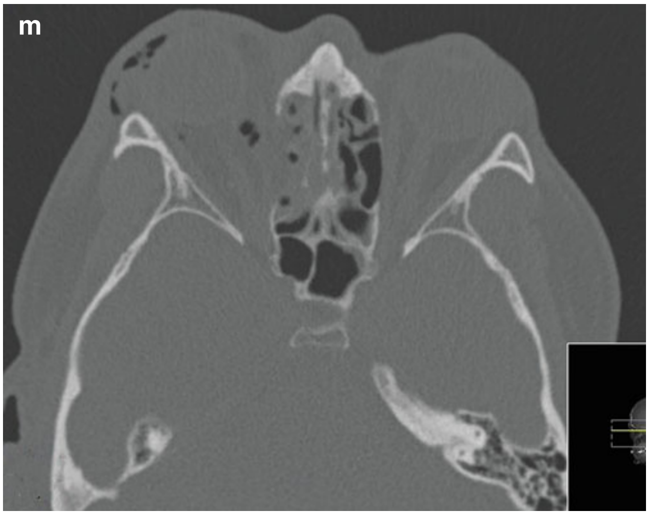


Fig. 9.106 (continued)

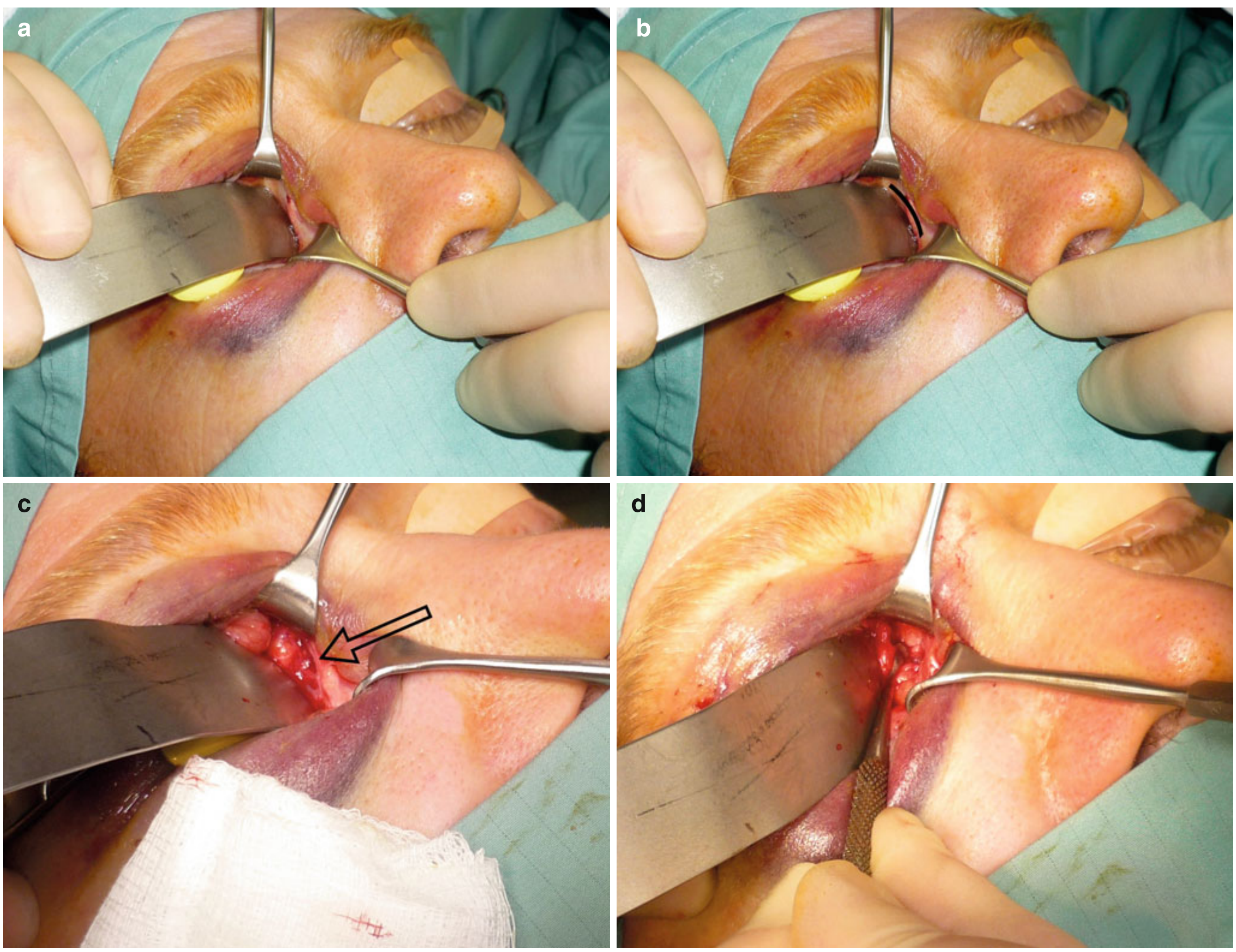


Fig. 9.107 In this case the incision is marked (**a**, **b**). Following tenotomy dissection to bone the periosteum is incised and elevated (**c**, **d**). The medial wall can be clearly seen (the defect is more posterior) (**e**, **f**). A strip of thick silastic cut to shape, makes a good retractor if your instruments are not the right size (**g**, **h**). Plate position is marked on a dry skull to aid understanding. Note that it tapers posteriorly. Also note the ethmoidal foramina (*red arrows*). Bleeding is common during this procedure. The plate can be seen (not fully seated yet) (**i**, **j**)

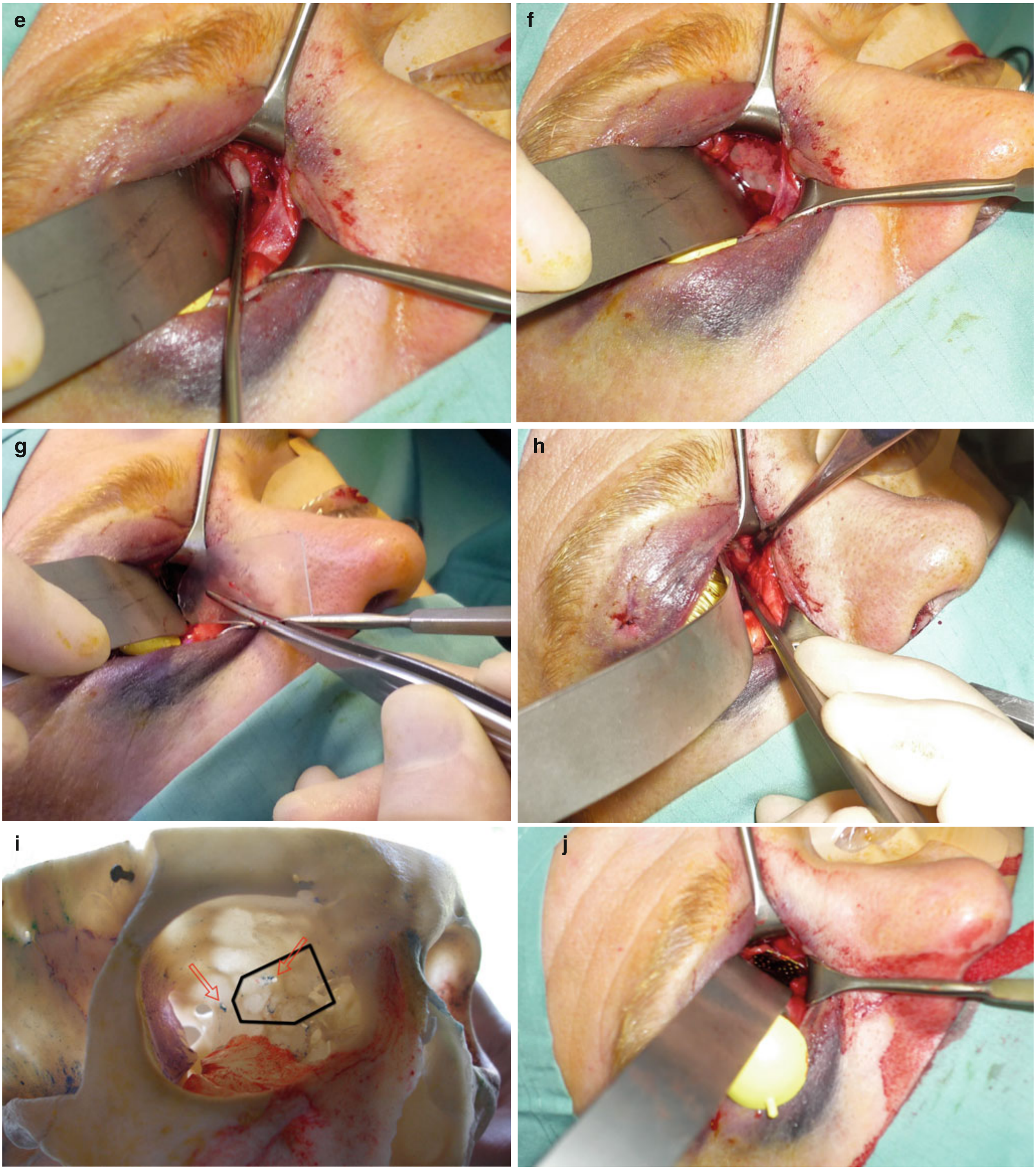


Fig. 9.107 (continued)

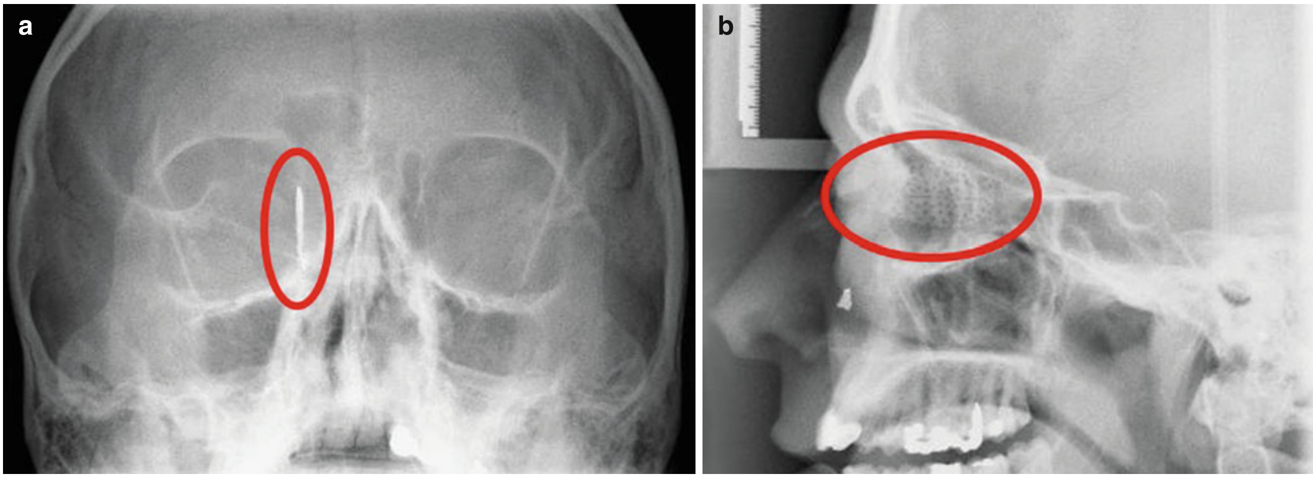


Fig. 9.108 Postoperative plain films show a satisfactory position (**a**, **b**). *Red circles* show the plate

9.4.2.2 Endoscopic-Assisted Repair

Transnasal endoscopic-assisted repair is a very useful technique that greatly assists the repair of medial wall fractures. This provides excellent visualisation of the defect, particularly in areas that are difficult to see through the approaches previously described. By combining transorbital access with an endoscopic-assisted transnasal approach, precise reconstruction of large orbital defects is possible. Needless to say, this requires skills in the operating of an endoscope and a good working knowledge of intranasal anatomy (*see* Figs. 9.109, 9.110, 9.111, 9.112 and 9.113).

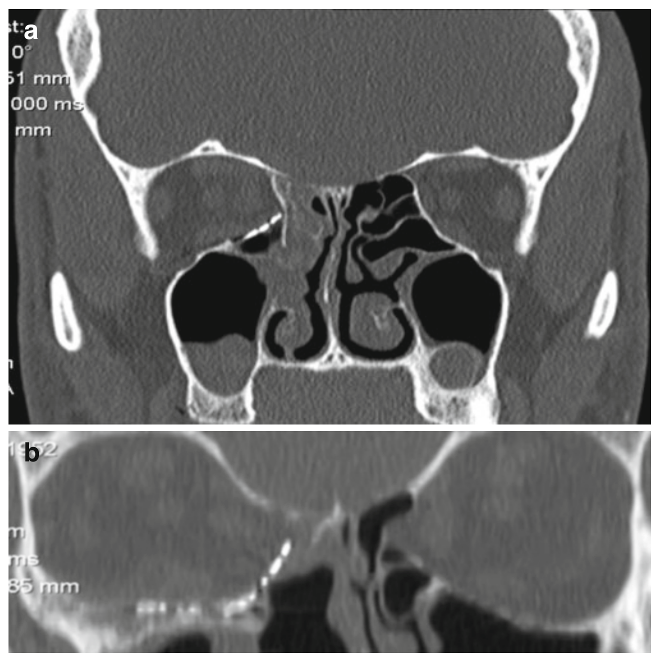


Fig. 9.109 Precise placement of plates in large defects can be very difficult without assisted techniques (**a**, **b**). Note malposition

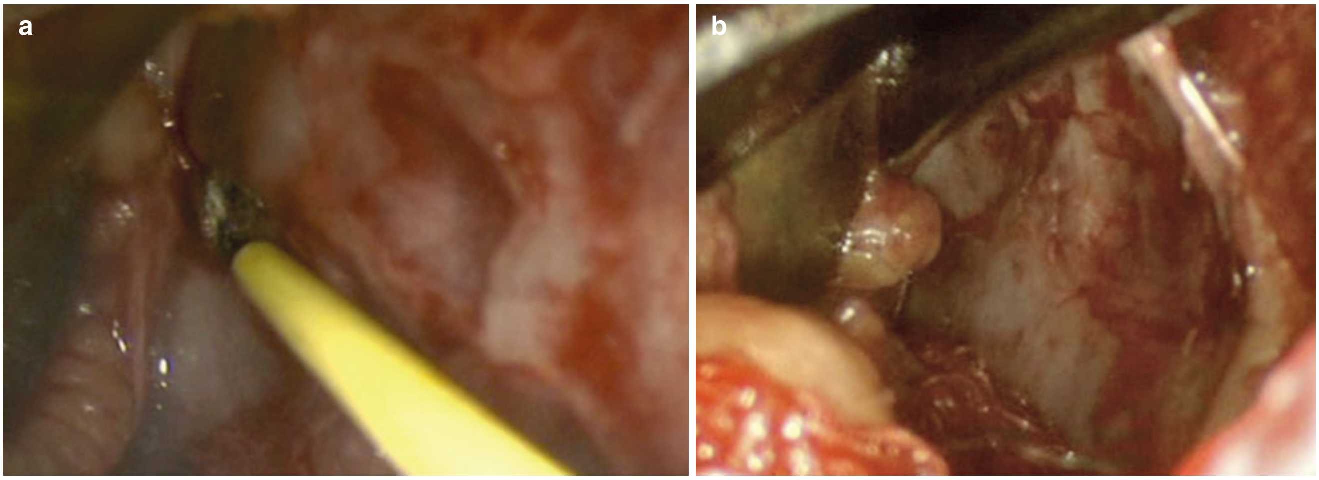


Fig. 9.110 Endoscopic techniques are a valuable adjunct if available. Visualisation of the medial wall and repair greatly facilitates accuracy (**a**, **b**)

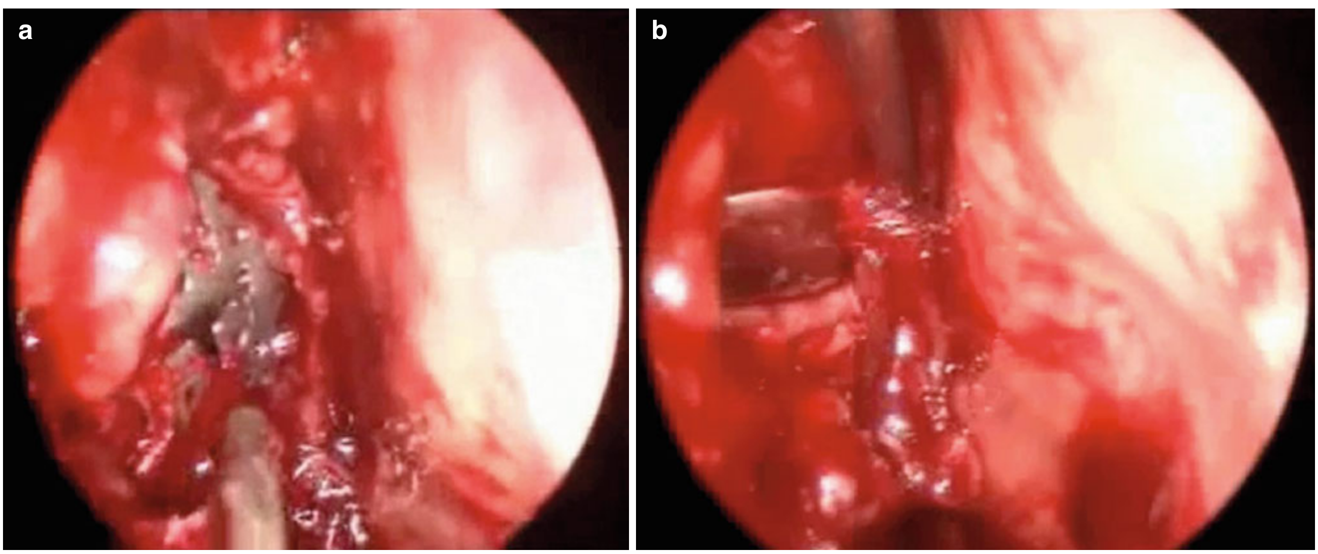


Fig. 9.111 Endoscopic view showing plate and elevator (**a**, **b**)

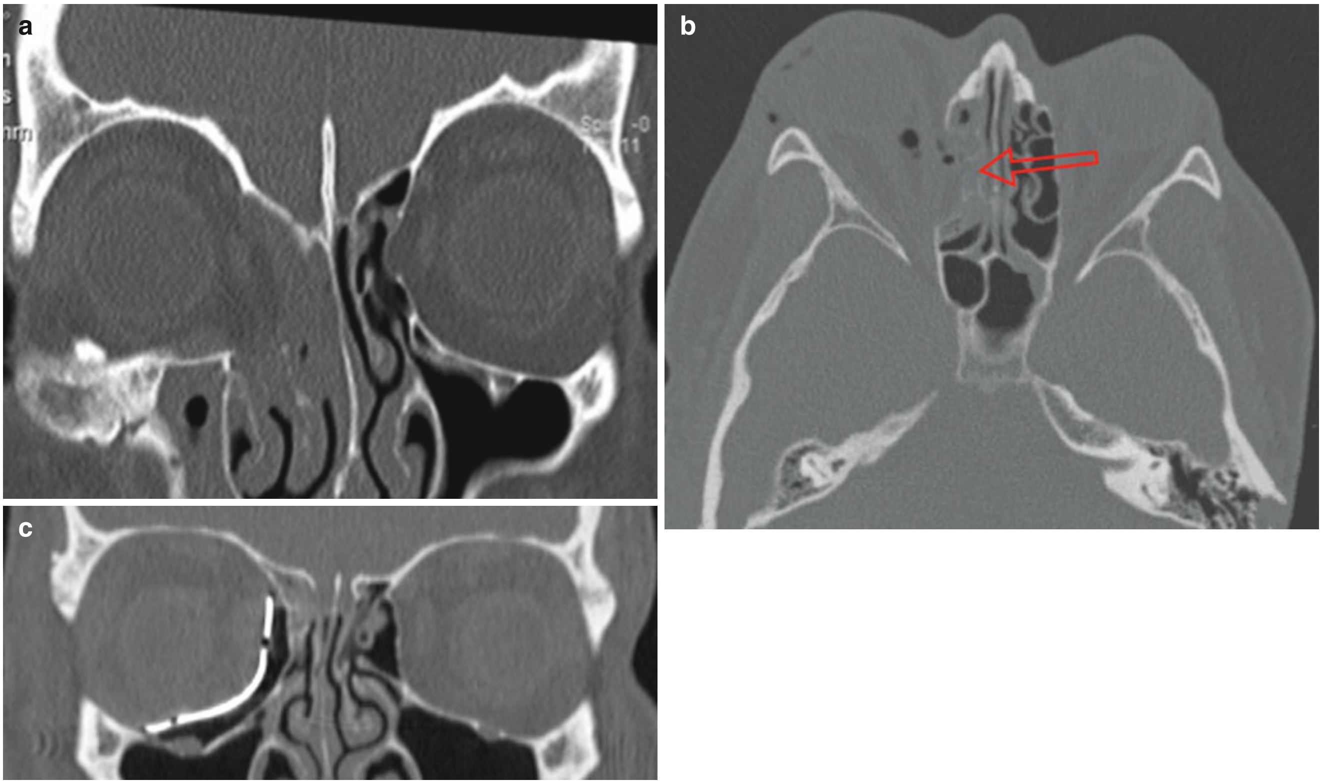


Fig. 9.112 Pre- and postoperative CT images (**a**–**c**)

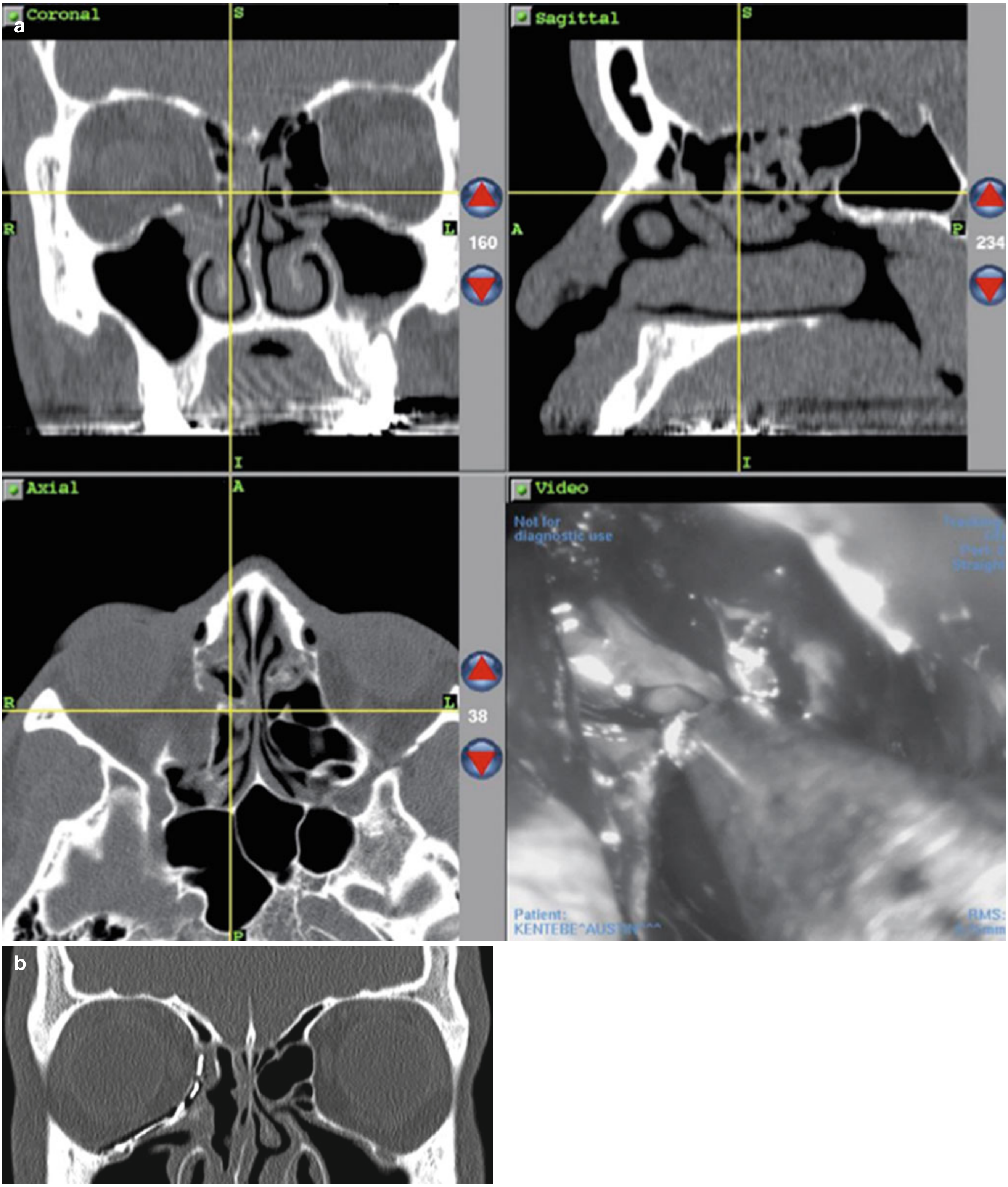


Fig. 9.113 Further example of precise repair possible using endoscopic-assisted techniques (**a**, **b**)

9.4.3 Orbitotomy

Access osteotomy is a familiar concept, particularly in head and neck cancer surgery. The excellent blood supply to the head and neck region gives us the opportunity to physically detach bone from its soft tissues, thereby gaining access to the deeper structures. Following management of these deeper structures (resection if malignant, clipping if vascular, repair if traumatic), the removed bone is then replaced and secured with plates.

In facial trauma, access osteotomy is not often required. However, occasionally it may facilitate the dissection and repair of large orbital fractures, particularly those that extend posteriorly, close to the orbital apex. By removing a segment of the orbital rim (usually the inferior rim), retractors can be better positioned and dissection less hindered.

Care is required when carrying out an orbitotomy of the infraorbital rim. The infraorbital nerve runs at a variable depth along the floor of the orbit and can easily be damaged.

In the case shown, the orbit has been accessed through a midtarsal incision. Following periosteal elevation, the rim is clearly defined. The infraorbital nerve should be clearly identified as it exits through its foramen. This can vary in position. The ends of the osteotomy are marked; the bigger the osteotomy, the better the access.

Prior to osteotomy, a relocation plate or plates can be prepared. These are placed along the rim, spanning the ends of the osteotomy line and then secured with one or two screws. The plates and screws are then removed and put aside. This technique should ensure that the fragment is returned precisely to its correct position (*see* Fig. 9.114).

Initial bone cuts are then made using a fine saw or burr. The cuts should be as thin as possible so that the bone fits precisely back into position at the end of the procedure. Using an apicecectomy burr, or some other suitable instrument, the lower (facial) end of each cut is continued into the infraorbital foramen, taking care not to damage the nerve. The orbital ends of each cut pass along the orbital floor to meet each other (again taking care not to damage the nerve). The cuts are then completed with a fine osteotome and the fragment gently lifted. This must be done carefully. The nerve may not be completely free and can sometimes run in a tunnel within the centre of the fragment. If so, the bone needs to be gently nibbled away to free the nerve. The free bone fragment is then wrapped in a damp gauze swab and set aside (*see* Figs. 9.115, 9.116, 9.117 and 9.118).

Following orbital repair, the fragment is then replaced and secured using the previously prepared relocation plates. Prior to this, any bony spicules on the undersurface of the fragment should be removed using bone nibblers and the foramen enlarged slightly. This hopefully reduces the likelihood of any nerve compression during healing (*see* Fig. 9.119).

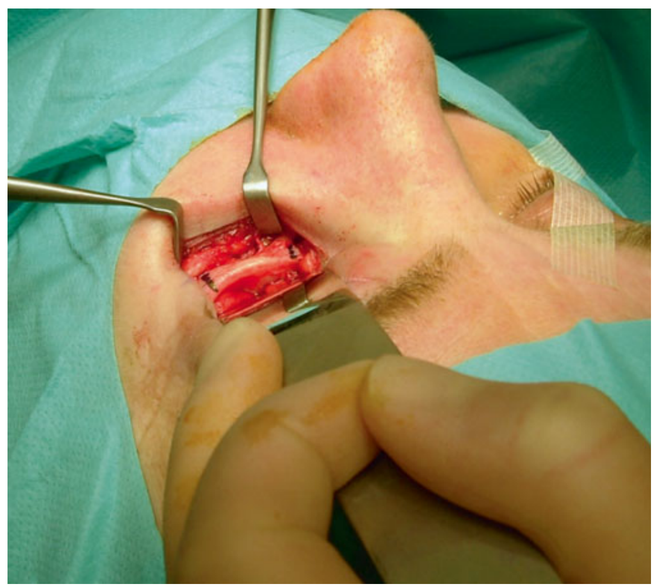


Fig. 9.114 Inferior orbitotomy. The rim has been marked prior to bone cuts. Prelocation plates may be placed at this stage

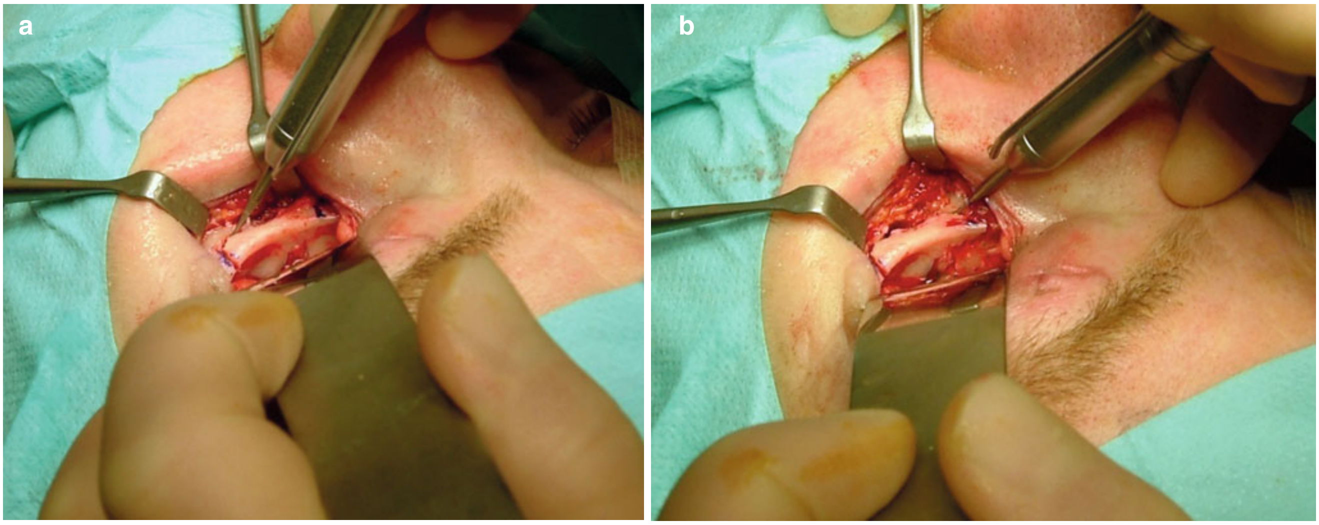


Fig. 9.115 Vertical bone cuts are made through the rim with a fine saw and joined to the foramen with an apicectomy burr (**a**, **b**)

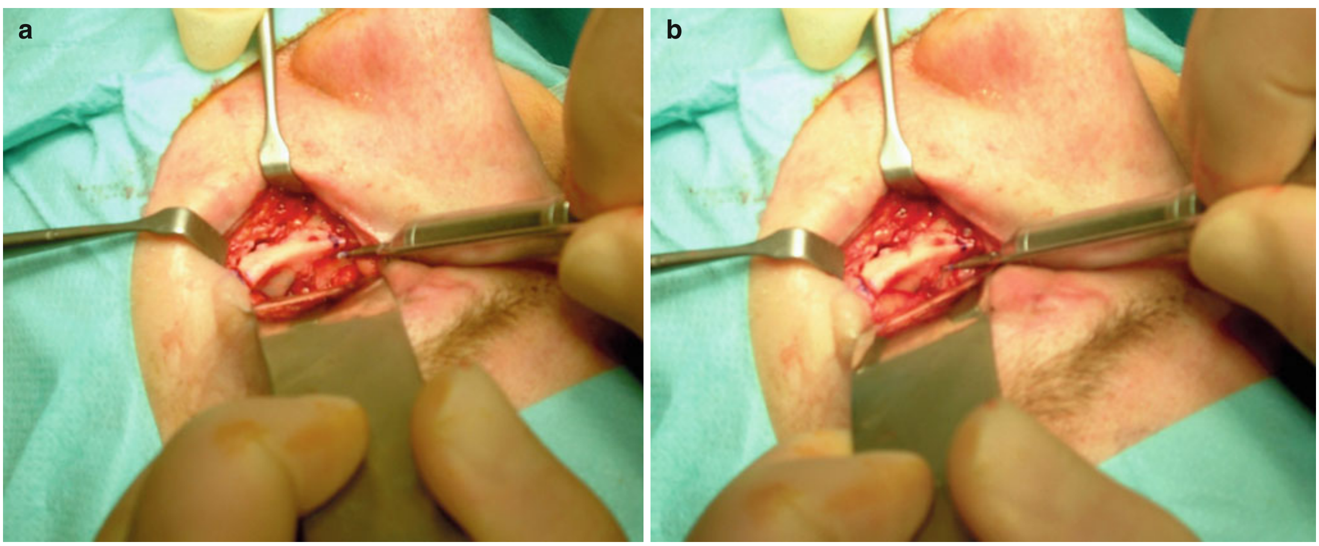


Fig. 9.116 The bone cuts are joined along the orbital floor (**a**, **b**)

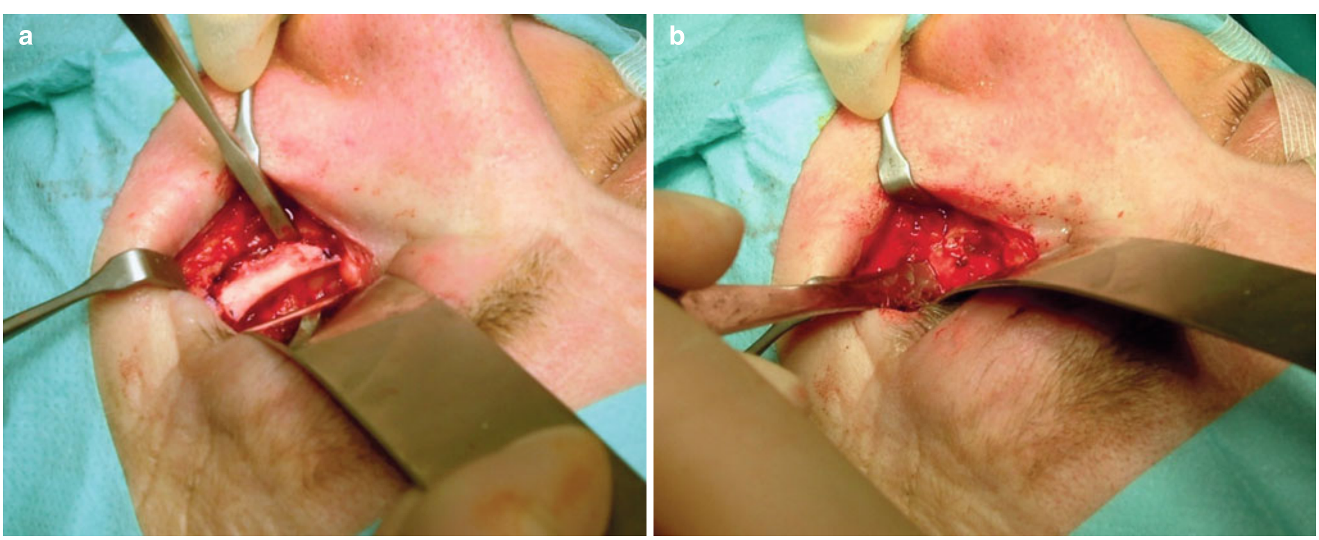


Fig. 9.117 These are completed with a fine osteotome and the fragment elevated carefully (**a**, **b**)

Fig. 9.118 Fragment and infraorbital nerve (**a**, **b**)

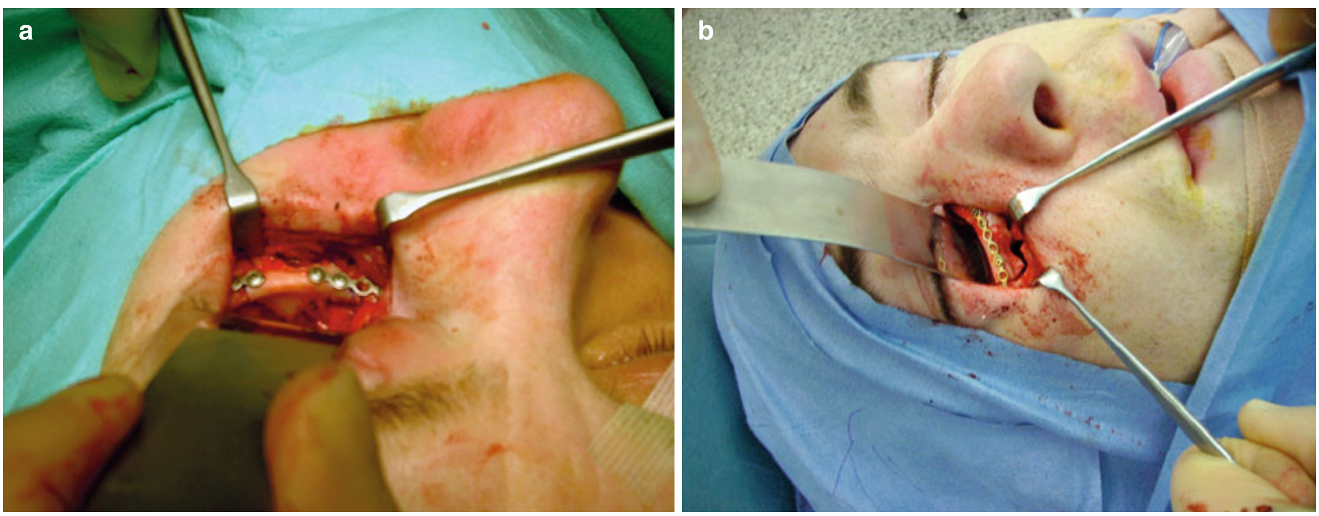


Fig. 9.119 The osteotomised rim has been returned and secured prior to wound closure (**a**, **b**)

9.5 The Forced Duction Test

The forced duction test is an important part of the assessment of orbital fractures. It is often undertaken to determine if there is any soft tissue entrapment resulting in restricted movements of the globe. The test can be carried out in the clinic under local anaesthetic if there is uncertainty regarding mechanical or neurological pathology. It should also be carried out following orbital floor exploration and repair, before the patient is woken up, to ensure there is no residual entrapment of soft tissues.

The principle of the forced duction test is very straightforward. The globe is gently rotated away from the suspected site of entrapment. Any residual tethering of the soft tissues will result in an abrupt cessation of rotation. The test may be performed in a number of ways. In the first example, fine tooth forceps are used to grasp the sclera in the 6 o'clock position just below the iris. The globe is then gently rotated upwards, as if the patient was looking up. This is the most common direction for entrapment, but the globe can also be rotated laterally with medial wall fractures (the sclera is grasped medially). Alternatively, the forceps may be passed deep into the lower fornices and the tendon of the inferior rectus muscle grasped. This needs to be carried out carefully to avoid damage to the eye or conjunctiva. The anaesthetist should also be warned beforehand, as pulling on the globe can result in profound bradycardia (*see* Figs. 9.120, 9.121 and 9.122).

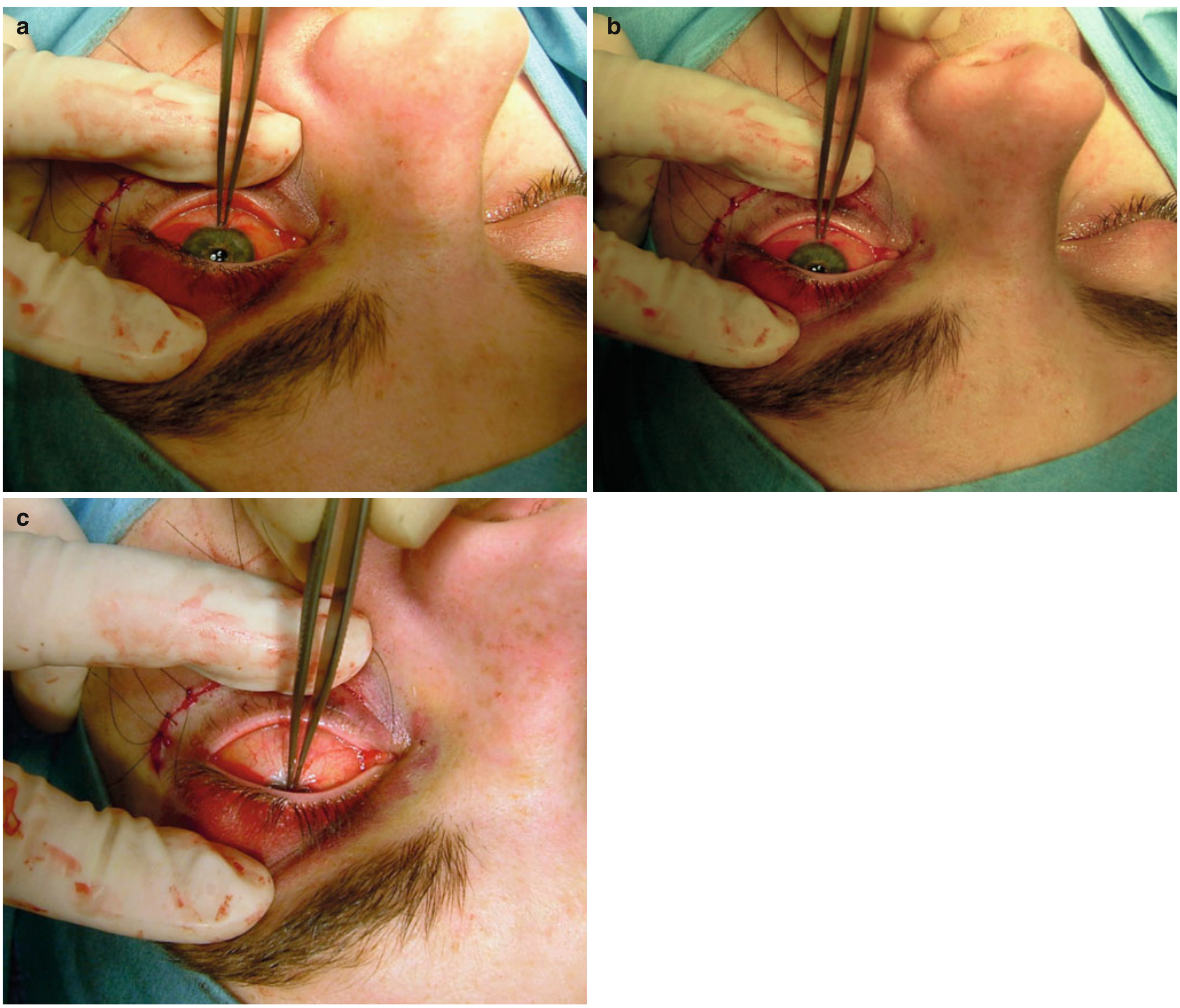


Fig. 9.120 Force duction test following repair of the orbital floor. The sclera is gently grasped and rotated up (**a**–**c**)

Fig. 9.121 Alternatively the inferior rectus tendon can be grasped

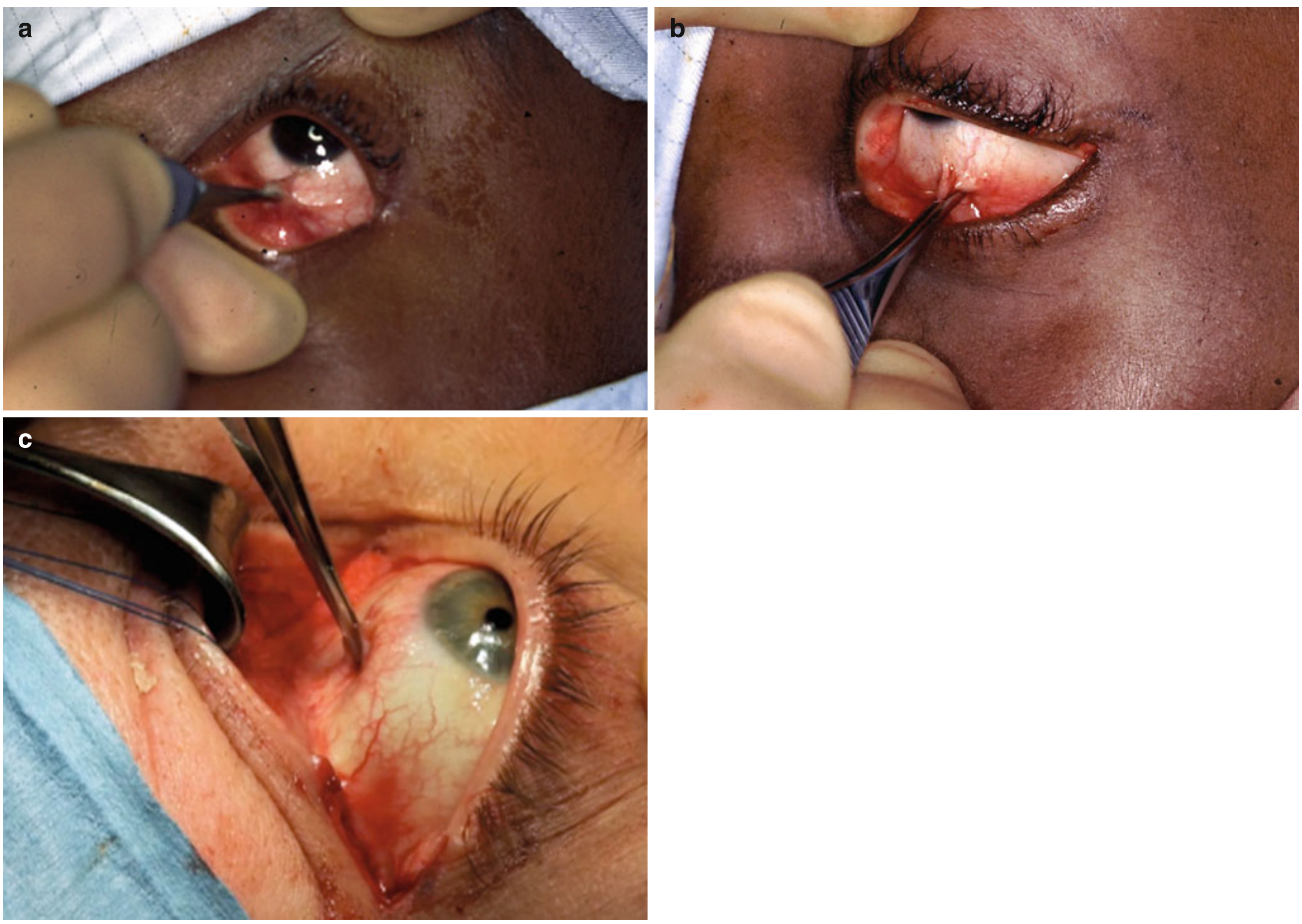


Fig. 9.122 Avoid repeated attempts at this (**a**–**c**). The conjunctiva can be damaged

9.6 Fractures of the Orbital Roof and Superior Orbital (Supraorbital) Rim

These are mentioned for completeness here, but depending on their size represent a “watershed” area between the skull base and frontal sinus. Various combinations of fractures therefore exist:

- Isolated supraorbital rim
- Supraorbital rim extending into the frontal sinus recess
- Surpaorbital rim extending into the anterior cranial fossa (orbital roof)
- Fractures involving all these sites.

Fractures involving the frontal sinus and skull base are discussed elsewhere. Needless to say, the extent of these fractures needs to be clearly defined if bone fragments are to be manipulated during repair. CT scanning is therefore essential. This also helps identify whether the fracture involves the supratrochlear or supraorbital foramina.

With larger fractures, access may require a coronal flap. However, such an extensive exposure may be difficult to justify for smaller fractures, which may just as easily be repaired through discretely sited local incisions, as shown.

Fig. 9.123 Vertical dystopia following cranio-orbital fracture. These serious injuries are discussed elsewhere

9.6.1 Repair of Supraorbital Rim

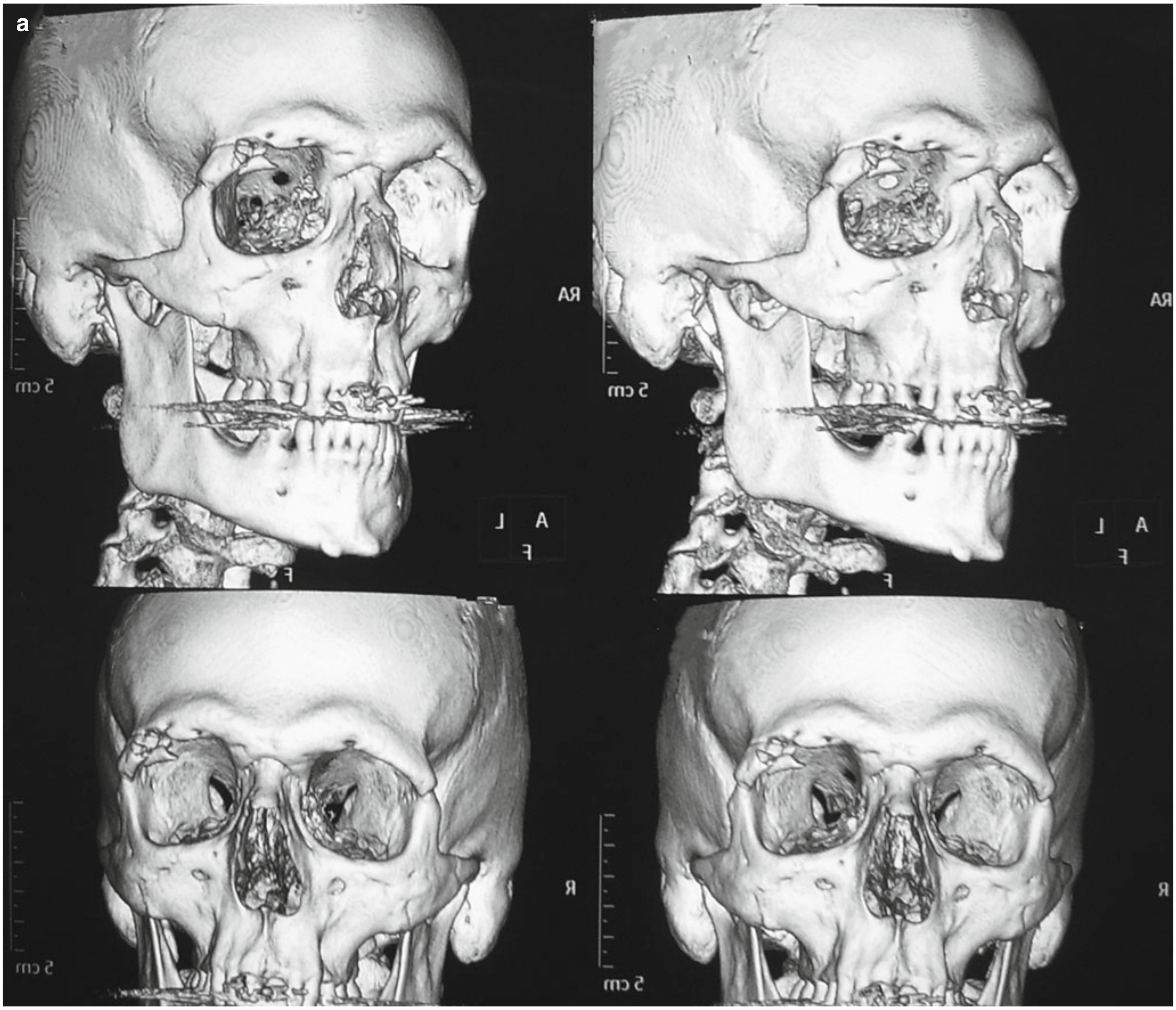


Fig. 9.124 Isolated rim fractures with displacement, pressing on the globe (**a**, **b**). There was mild dystopia. The fragments and lateral incision were marked. Initial exploration was through the overlaying laceration (**c**, **d**). Surprisingly good access and exposure of the fragments was possible (**e**, **f**). Subperiosteal dissection exposed the fragments (**g**, **h**). The main fragment was removed for extracorporal repair (**i**, **j**). The fragment was returned and secured. Closure was in layers (**k**, **l**)

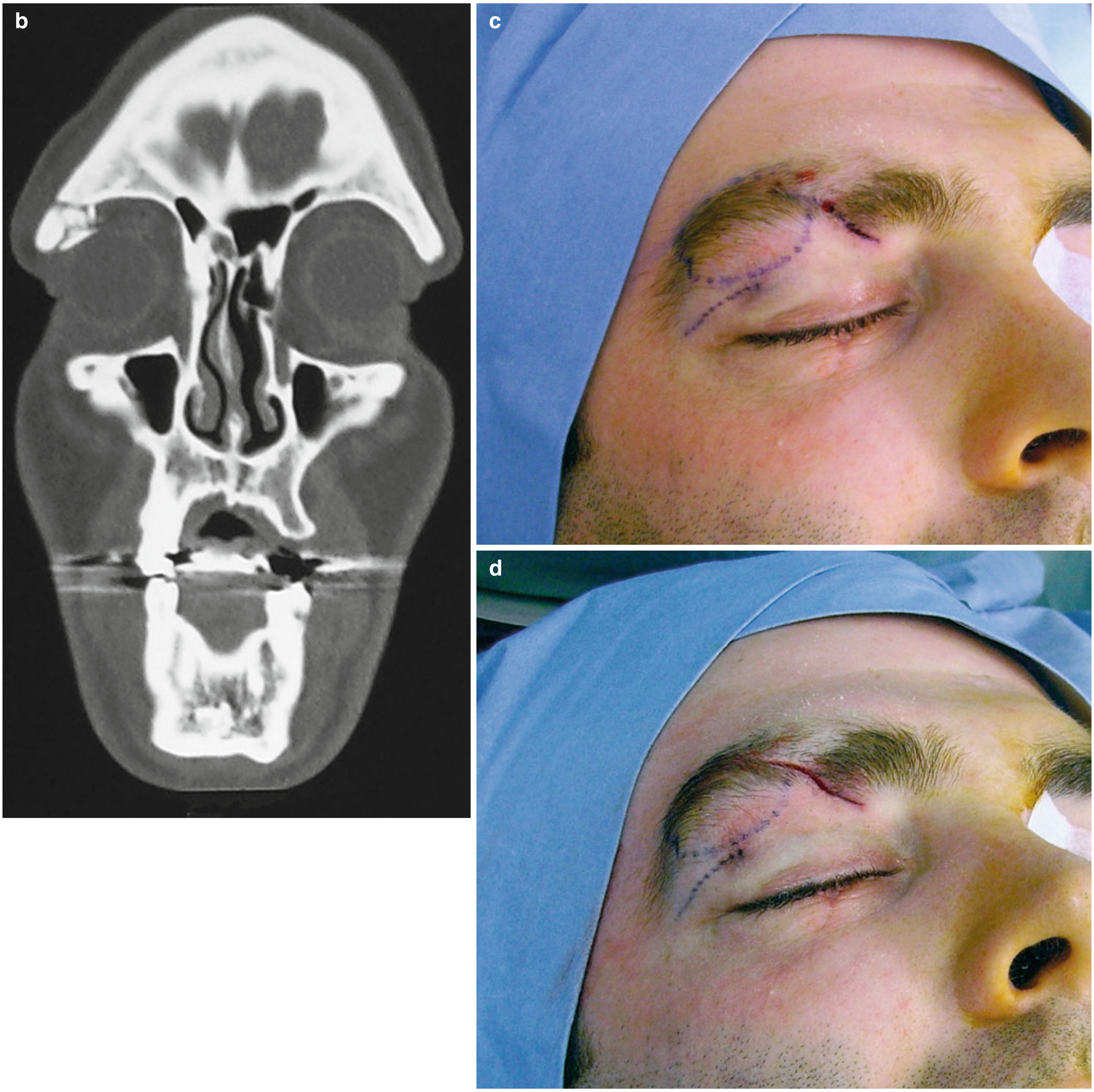
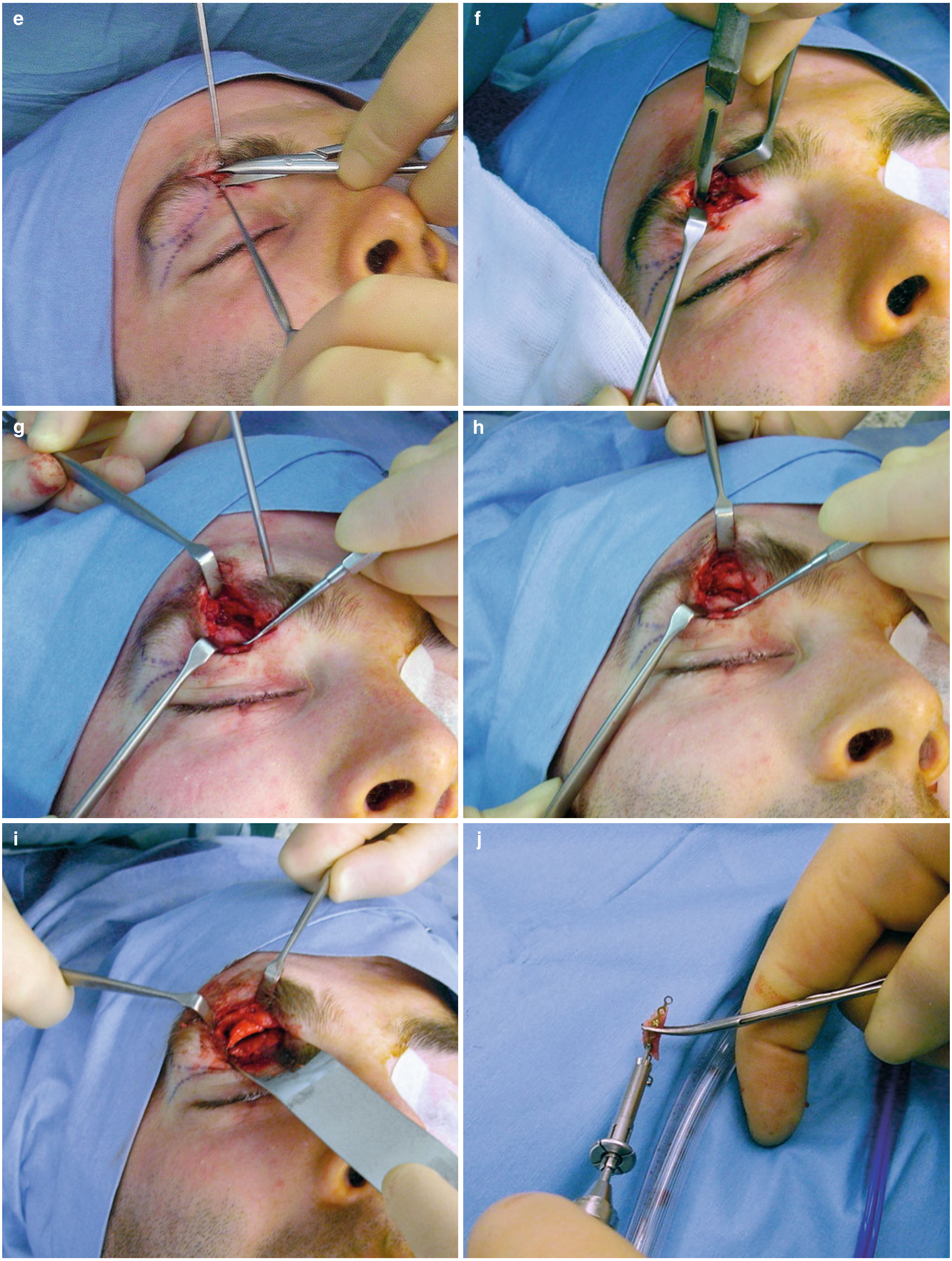


Fig. 9.124 (continued)



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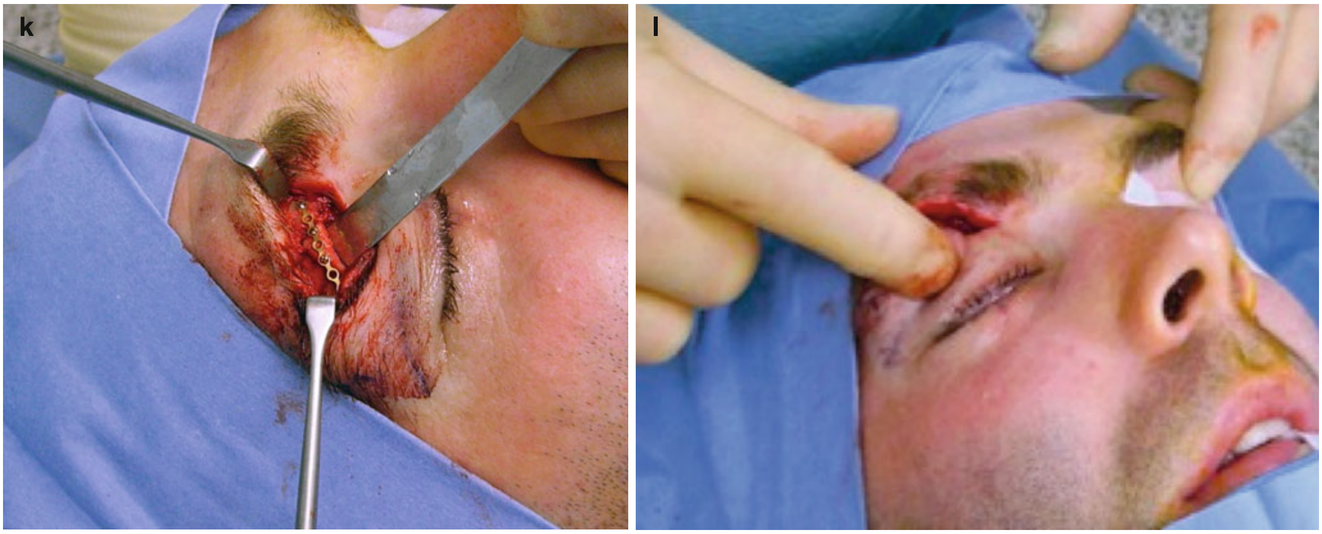

Fig. 9.124 (continued)

Isolated orbital roof fractures are rare. In adults they may be managed nonsurgically, as the bone remodels, although some surgeons may elect to repair them using titanium or bone grafts. Patients can rarely develop pulsatile exophthalmos. This may require repair if it does not settle. Since these are also skull base fractures, risk-benefit analysis of any repair must be carefully considered and the advice of a neurosurgeon sought. If the bone fragments are significantly displaced, a dural tear is likely.

9.7 Orbital Apex Fractures

Fractures of the orbital apex commonly occur in association with fractures of the zygoma and orbit. They are also seen in association with other craniofacial fractures. Either way, these occur following high-energy injuries and as such may also be associated with injuries to the cervical spine, brain, or globe. The orbital apex is the deepest part of the orbit and forms part of the craniofacial junction.

9.7.1 Applied Anatomy

The anatomy in this region is complex due to the neurovascular structures that pass through the optic canal (OC) and superior orbital fissure (SOF). These are two separate channels, between which lays a thick strip of bone, sometimes referred to as the optic strut.

Medially, the optic canal has a close relationship to the sphenoid sinus. In some patients the sinus can be enlarged to such an extent that it almost engulfs the canal, increasing the risks of fractures. Through the optic canal pass the optic nerve and ophthalmic artery. Since the optic nerve is essentially an extension of the brain it is enveloped by pia mater, arachnoid, and dura mater. These collectively form a nerve sheath. Although this is generally mobile throughout most of its length, within the canal itself the nerve sheath is relatively tethered and is therefore at risk of shearing forces. For this reason blindness can be associated with blunt forehead trauma, even in the absence of any fractures.

The superior orbital fissure (SOF) lies between the greater and lesser wings of the sphenoid, i.e., between the orbital roof and lateral wall of the orbit. A ligamentous ring, the annular ligament (or common tendon) of Zinn, spans the fissure and passes around the optic canal. From this ligament the four recti muscles arise. The ligament therefore divides the fissure into an intraconal and an extraconal portion, through which different cranial nerves and vessels pass (*see* Fig. 9.125).

These structures are:

Superior and inferior divisions of the oculomotor nerve (III)
Trochlear nerve (IV)
Lacrimal, frontal and nasociliary branches of the ophthalmic nerve (V1)
Abducens nerve (VI)
Superior and inferior divisions of ophthalmic vein

Orbital apex fractures commonly occur following high-energy blunt trauma or penetrating orbital trauma. Radiographically, three types of injury have been described:

1. Linear without displacement of fragments
2. Comminuted with fracture displacement
3. Apex avulsion with an intact optic foramen.

Since the sphenoid sinus is also usually fractured, these are technically open fractures and therefore at risk of contamination.

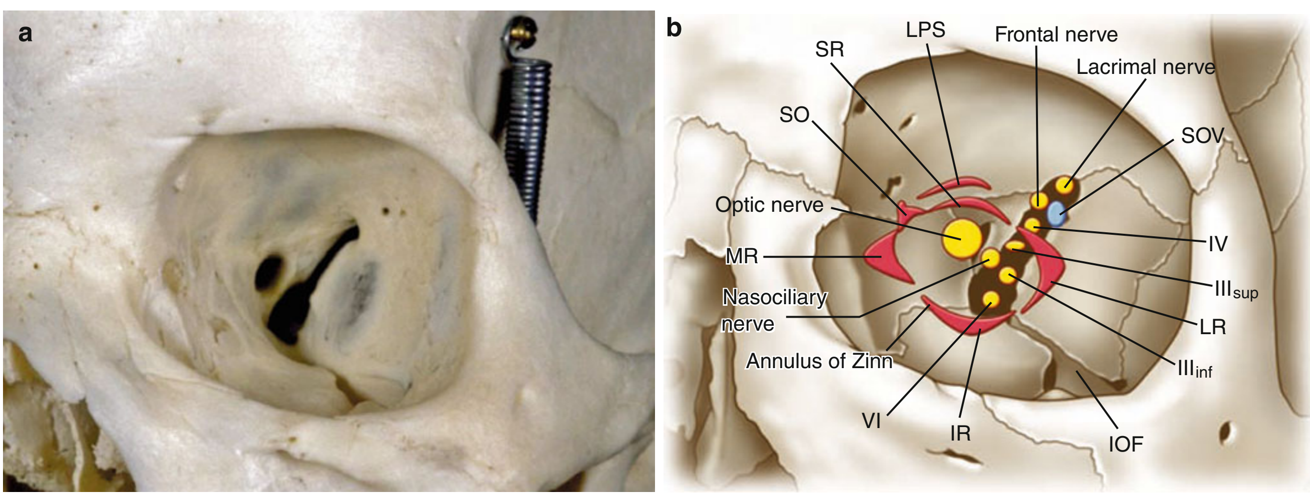

Fig. 9.125 The orbital apex: a complex anatomical site (**a**, **b**)

9.7.2 Clinical Features

Symptoms and signs vary, depending on which neurovascular structures are damaged and their severity. Various syndromes have been described (*see* Table 9.6).

Visual impairment from traumatic optic neuropathy can occur and may be partial or total, with variable recovery. An afferent pupillary defect is highly suggestive of optic nerve injury and this may be the only clue in the unconscious patient. It is important to remember that these syndromes can occur in the absence of fractures—fractures of the optic canal are reported to be present in only half of patients with traumatic optic neuropathy. Injury may therefore arise from one of several mechanisms. These include:

- Optic nerve transection
- Nerve sheath hematoma
- Optic nerve compression
- Microhaemorrhages within the nerve (cf diffuse axonal haemorrhage)

Table 9.6 Clinical syndromes

Superior orbital fissure syndrome (also known as Rochon-Duvigneaud's syndrome)
Injury to the cranial nerves passing through the fissure results in diplopia, paralysis of the extraocular muscles, proptosis, and ptosis
If blindness or visual impairment is also present with these features, it is called an orbital apex syndrome

Traumatic optic neuropathy is believed to occur when energy is transferred towards the orbital apex and optic canal at the time of injury. Due to the narrowness of the canal and tethering of the nerve within it, only a small amount of elastic deformation is required to result in nerve injury and swelling, etc. Shearing forces result in contusion, ischemia, and micro-infarction of the axons, followed by oedema. If there is a fracture at the apex, bony impingement followed by oedema and hemorrhage occur. Hence management can vary. The presence of associated intracranial injuries also has a major impact on management. Investigations are shown in Table 9.7.

Table 9.7 Investigations of orbital apex injuries

CT scan
Fine cuts are required to assess the orbital apex (specifically for nerve transection or compression). Associated intracranial injury, facial fractures, and cervical spine injuries should be screened for
Angiography
This may be considered in patients with orbital apex fractures. Such high-energy injuries can also result in carotid and cavernous sinus injury. Carotid artery dissection, spasm, or caroticocavernous fistula should be considered
MRI
This is rarely undertaken acutely. However it can have a role in identifying hemorrhage within the optic nerve or sheath
Visual field assessment
Visual-evoked potentials (VEP)
These can assess the integrity of the visual pathway. They are particularly useful in patients with altered level of consciousness

9.7.3 Management

These are serious and difficult injuries to manage and require a multidisciplinary approach. Neurosurgical input is indicated if there is any intracranial injury and ophthalmology input if there are any signs of globe injury or visual impairment. The advice of a radiologist should also be sought to determine the best imaging and screening protocol for occult injuries (e.g., caroticocavernous injury).

Management is a controversial area and depends on the patient's specific injuries, presence of any functional deficits, and their overall condition. Clearly any neurosurgical emergencies take precedence and this may restrict specific measures directed at the orbital apex.

Three main treatment options exist. These include observation, high-dose steroids, and surgical decompression. However, currently there appears to be no clear evidence that supports one modality over the others. Since spontaneous visual recovery has been shown to occur in a significant number of patients (approximately 40–60 %), the decision to treat these injuries surgically or with high-dose corticosteroids therefore requires clinical judgment.

High-dose corticosteroids have been used with variable effect in the treatment of traumatic optic neuropathy. Care is required in certain patients (e.g., diabetics, or those with peptic ulcers, osteoporosis). Furthermore, there is now evidence to suggest that the use of corticosteroids in patients with acute traumatic brain injury increases mortality. In those patients suitable for steroid treatment, the type and optimal dose is still unclear.

Outcomes from surgery are very technique-dependent, as access to the orbital apex is difficult. In cases where vision is decreased (or decreasing) from optic nerve injury, decompression may be indicated if steroids have failed. Progressive swelling in the canal (from oedema and bleeding) is effectively a form of compartment syndrome, and this results in ischaemia and infarction of the axons. Theoretically, decompression may salvage those nerves with reversible injury. However, there is no clear evidence that removing bony fragments will improve the chance of recovery. Surgery itself may result in further trauma and damage. Several techniques exist:

- Medial approach via an external ethmoidectomy
- Inferomedial access via a transantral/transethmoidal approach
- Transfrontal craniotomy
- Endoscopically

Recent advances in endoscopic techniques now mean that decompression can be undertaken intranasally via a transethmoidal or transsphenoidal approach. This clearly has advantages over the more invasive external approaches, with decreased morbidity and faster recovery time.

Management of ocular motility problems falls under the care of specialists in strabismus. In many cases of superior orbital fissure syndrome, significant recovery of the muscles often occurs, although this can take many months (*see* Fig. 9.126).

Fig. 9.126 Superior orbital fissure syndrome

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Nasal Fractures

10

Michael Perry and Simon Holmes

These common injuries form a heterogenous group varying from relatively low-energy "en bloc" type fractures, to high-energy injuries, resulting in extensive and open (compound) comminution of the nasal bones, external cartilages and septum. Even higher energy impacts can result in "nasoethmoid" fractures, or can extend to involve the anterior cranial fossa. Fractures extending beyond the nose are discussed elsewhere in this book. Management of the "broken nose" can therefore vary considerably from the simple "MUA" (manipulation under anaesthesia) to more complex open approaches, with or without internal fixation of the bones, or bone grafting.

> In all nasal fractures, careful assessment and management of the septum is crucial. Failure to do so may result in deviation of the nose, or septal collapse with loss of projection.

Varying fractures patterns have been described (*see* Table 10.1 and Fig. 10.1).

Table 10.1 Patterns of nasal fractures (From Stranc and Robertson 1979)

Type 1	Injuries do not extend beyond a line joining the tip of the nasal bones and the anterior nasal spine. These fractures involve the cartilaginous nasal skeleton only
Type 2	Fractures are limited to the external nose and do not pass into the orbits
Type 3	Fractures extend into the orbital walls and/or skull base with varying degrees of displacement. These are often referred to as nasoethmoidal fractures
Another simple way to classify these is to consider the fractures in terms of comminution to the bones and septum. This helps treatment planning	
Type 1	"En bloc" fractures (with minimal comminution)
Type 2	Moderately comminuted
Type 3	Severely comminuted

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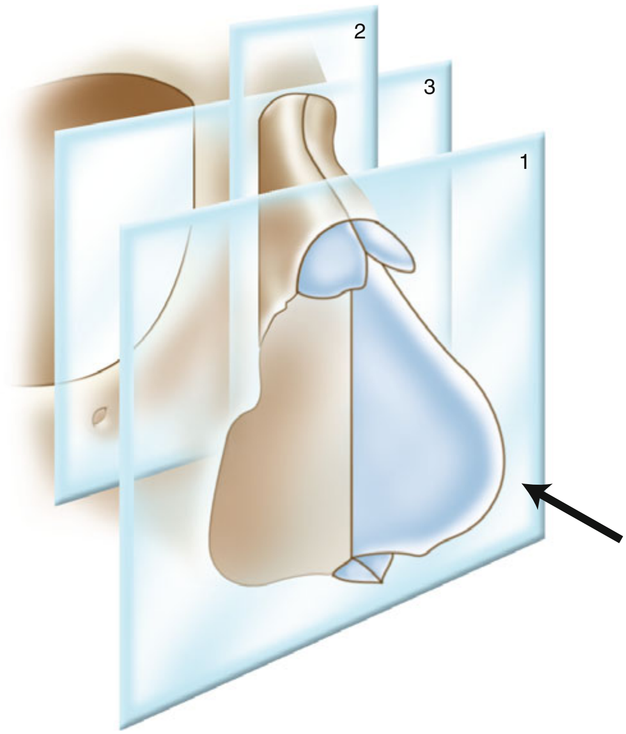

Fig. 10.1 Schematic view of varying planes of nasal fractures (*see* Table 10.1). *Arrow* indicate direction of force

Generally speaking, the greater the impact at the time of injury, the more extensive, comminuted and possibly deeper are the fractures. The mechanism of injury is therefore important to alert us to the possibility of cranial base or orbital involvement. As with all fractures, the extent of soft tissue damage plays a major role in management, complications and final outcomes.

10.1 Applied Anatomy

The bony and cartilaginous skeleton of the nose is often referred to as the nasal "pyramid." This is composed of the nasal bones, frontal processes of the maxilla bilaterally and the nasal cartilages. The nasal bones are relatively thick superiorly where they are attached to the frontal bone, but are thinner inferiorly where the upper lateral cartilages are attached. Hence they are more susceptible to fractures lower down.

The upper lateral cartilages are attached to the undersurface of the nasal bones. This is a key area in both aesthetics and function. Injuries here can result in collapse of the bones and/or upper lateral cartilages, which is not only cosmetically disfiguring but can impair nasal breathing. The upper lateral cartilages articulate with the lower lateral (or alar) cartilages. This overall arrangement is sometimes referred to as the "nasal valve." The paired lower lateral cartilages along with the septum define the position and shape of the nasal tip (*see* Fig. 10.2).

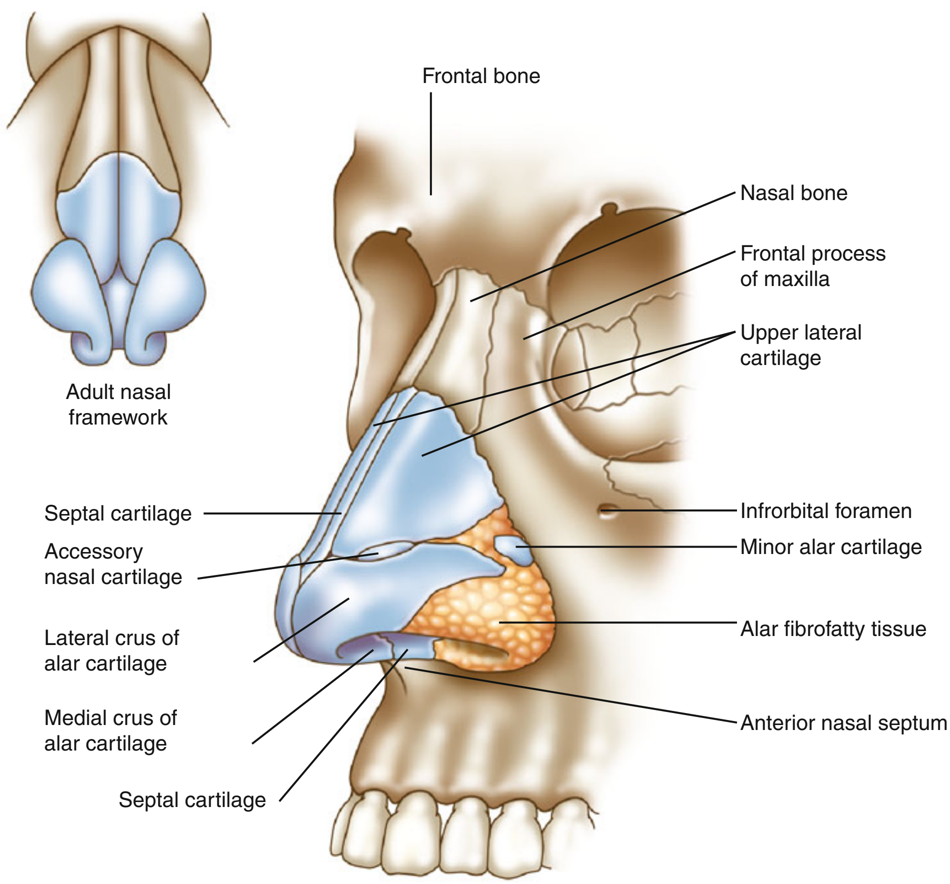

Fig. 10.2 Adult nasal bony and cartilaginous framework

Within the nasal cavity, the septum is made up of the following components (*see* Fig. 10.3):

- The quadrangular (septal) cartilage anteriorly
- The vomer inferiorly, and
- The perpendicular plate of the ethmoid posteriorly

The septum is a key structure in maintaining nasal projection and the midline position of the nose. Internally, the lateral nasal walls support the three pairs of conchae (superior, middle, and inferior). These make up the turbinates.

The ophthalmic artery (a branch of the internal carotid artery) divides into the anterior and posterior ethmoidal artery and the dorsal nasal artery. Injuries to these vessels can result in significant bleeding.

Nasal skin varies considerably in thickness both throughout the nose and between individuals. Where it is thin it can be easily torn, either during the initial injury or its subsequent repair. Minor irregularities in the underlying bones (and fixation plates) will also be more readily palpable following repair.

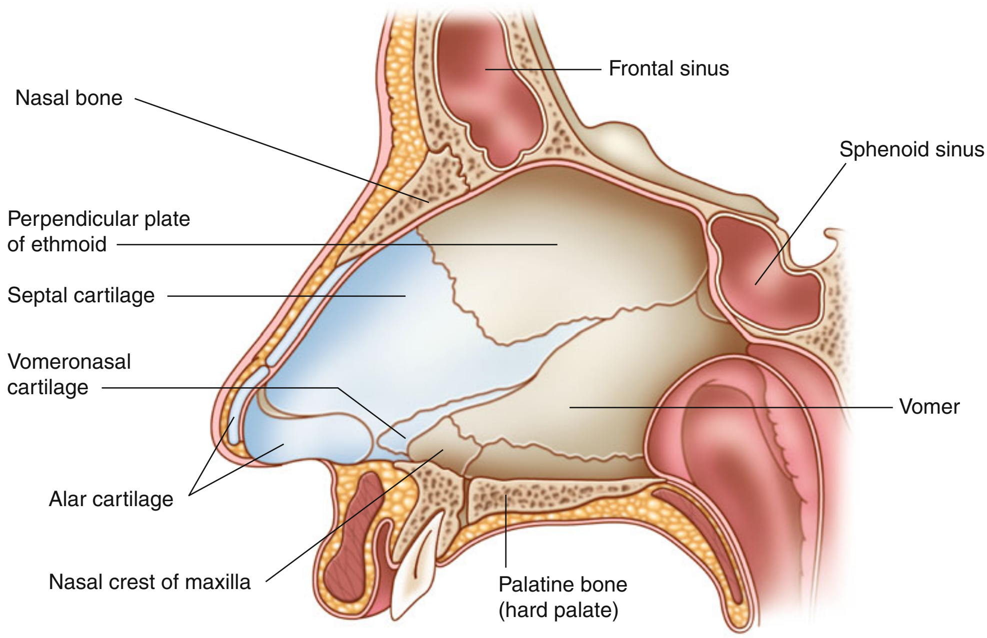

Fig. 10.3 Septal anatomy

10.2 Clinical Assessment

> Beware nasal fractures with extensive "black eyes"—consider the possibility of deeper fractures (e.g., naso-ethmoid or skull base injuries).

Diagnosis of nasal fractures is usually clinical, not radiological, although radiographs may be required if other injuries are suspected. In high-energy injuries, fracture propagation along the medial orbital wall can result in injury to the optic nerve. This is rare. A direct force applied to the bridge of the nose can also result in fractures of the anterior skull base (cribriform plate), resulting in cerebrospinal fluid (CSF) leakage. Such fractures complicate the diagnosis beyond a fractured nose and should be considered as upper midface or nasoethmoid fractures. It is therefore important to ensure that fractures have not extended into the ethmoid region or skull base. If this goes unrecognised, any manipulation of the bones can result in blind manipulation of these deeper fragments, with risks of blindness and dural tears. When such injuries are suspected, computed tomography (CT) scanning is indicated. Assessment therefore needs to be thorough and systematic (*see* Table 10.2).

Common clinical findings include epistaxis, swelling, and tenderness of the nasal dorsum, bruising around the eyes, and obvious deformity. There is often a degree of mobility and crepitus.

Table 10.2 Assessment of nasal fractures

Consider the following:
Mechanism of injury: are significant injuries likely?
Has the bleeding stopped? (especially if the patient is supine)
CSF leaks (cribriform plate fractures): ask patient to lean forward and refrain from sniffing. Watch for watery discharge
Visual acuity: high-energy fractures can extend along the medial orbital walls to the apex
Septal haematoma: needs urgent evacuation
Septal deviation resulting in reduced air entry
Lacerations (both externally and intranasally) +/− exposed bone/cartilage
Nasal deviation: ideally compare to recent pictures of patient
Is the intercanthal distance normal?
Could this be an old injury?

10.3 The Septum

Intranasal examination should be undertaken with proper lighting and a nasal speculum. The nasal septum is a key component in both the assessment and repair of nasal injuries. Not only does it provide nasal projection but it also defines the midline position of the nose. If the septum is significantly deformed this can also result in nasal obstruction. Due to its inherent elasticity, the septum can slowly change shape following manipulation or other procedures. This explains why a nose may appear "straight" on the operating table, yet the final result months later can be disappointing, when the nasal tip drifts to one side.

10.3.1 Septal Haematoma

Septal haematoma develops as a result of bleeding into the subperichondrial space (between the septal cartilage and the overlying, closely adherent perichondrium). This appears as a dark red swelling on the septum and results in partial nasal obstruction, usually within the first 24–72 h. Untreated it can become infected, leading to septal abscess (with a risk of intracranial extensions). Alternatively the septum can undergo avascular necrosis with loss of cartilage and septal perforation. Depending on the size of a septal perforation, patients can be troubled by nasal "whistling," crusting, or recurrent epistaxis. Larger defects can result in collapse of the entire septum, resulting in a "saddle nose" deformity.

> Septal haematomas may become infected within a few days of injury. Therefore they require urgent incision and drainage.

Incision and drainage can be performed under local anaesthesia. The mucosa is incised over the greatest area of fluctuation, without incising cartilage. If the haematoma is bilateral, the incisions should be staggered to avoid a through-and-through perforation. The clot is evacuated with suction and the wound is irrigated. Some authorities recommend excising a small piece of the mucoperichondrium to prevent premature closure of the incision. This prevents any recollection of blood. A drain may also be necessary. The nose is then lightly packed. Broad-spectrum antibiotics should be administered and specimens should be sent for culture.

10.4 Management of Nasal Fractures

10.4.1 Treatment Immediately After Injury and in the Emergency Department

If a confident diagnosis of an isolated nasal fracture is made immediately after a low-impact injury (for example at a sporting event), a gentle attempt at repositioning the nose may be possible in some patients before swelling develops. Lightly packing or gently pinching the nose may help arrest any minor haemorrhage. Light cold compresses can help reduce swelling. However, manipulation is best avoided if more extensive fractures are suspected following higher energy impacts. It can also be quite uncomfortable for the patient and may aggravate bleeding.

Isolated nasal fractures rarely result in life- or sight-threatening complications. However, profuse nasal bleeding in elderly patients can occasionally compromise their cardiovascular system. Despite obvious concerns, packing of the nasal cavity in the presence of skull base or nasoethmoid fractures is possible, so long as it is undertaken by an experienced practitioner and with due care. The risks of intracranial or intraorbital displacement of the packs are often over-emphasised and in an actively bleeding nose something needs to be done. The risks and benefits therefore need to be carefully weighed up.

10.4.2 Decision to Operate

Indications for the manipulation or repair of nasal injuries can be considered as functional or aesthetic (*see* Table 10.3). Difficulty breathing through the nose is a common problem following deviation of the nasal pyramid and septum. This also results in unsightly appearances.

Table 10.3 Indications for surgery

Acute
Septal haematoma
Uncontrollable epistaxis
Delayed
Nasal deformity
Obstructed nasal airway

Remember to ask the patient if the shape and function of the nose has actually changed since their injury. Unfortunately, some patients may take this opportunity to have a longstanding problem corrected—something which is not possible by simple manipulation!

In some cases it may be preferable to defer surgery and investigate further, particularly when there are concerns regarding possible CSF leaks, ocular injuries, or more extensive fractures. However, in the absence of these complications, most cases can be managed by manipulation under anaesthesia. Open reduction and internal fixation (ORIF) through an overlying laceration or suitably sited skin incision may also be indicated. The decision to ORIF nasal injuries depends on a number of factors, notably the presence of lacerations, degree of comminution, and size of each bone fragment. Generally speaking, manipulation is carried out approximately 5–10 days after the injury when the swelling has resolved. This makes manipulation and on-table assessment much easier. If there is an open wound (externally or internally), then repair should be expedited and carried out sooner if possible.

10.5 MUA Nose

> Wet plaster of Paris (POP) is a caustic solution and highly irritant to the eyes. Placement requires care. Don't apply a dripping wet slab to the face.

Manipulation of the nasal bones is a common yet often underappreciated procedure, which if performed poorly can result in residual deformity. The "quick tweak" in the anaesthetic room is not surprisingly accompanied by poor outcomes, and careful assessment is very important. Failure to straighten the septum will inevitably result in some relapse, even if the nose appears straight at the end of the procedure. This is due to cartilage's inherent elasticity. Attention to the septum is therefore an important part of this procedure.

Digital manipulation of the nose may be possible in "low-energy" fractures where the nose has been displaced "en bloc," with buckling or bowing of the septum. In such cases it may be possible to reposition the nasal pyramid relatively easily as shown. Once repositioned, Steri-Strips (or suitable equivalent) are applied to the skin and a splint placed. Splints can be fabricated from a number of materials (*e.g.*, plaster of paris, adhesive aluminium, acrylic and impression compound). All have the potential to irritate the skin, so choose carefully and protect the skin with Steri-Strips before placing the splint (*see* Figs. 10.4, 10.5, 10.6 and 10.7).

Fig. 10.4 Simple nasal fracture requiring gentle digital manipulation. Case selection is important (**a**, **b**)

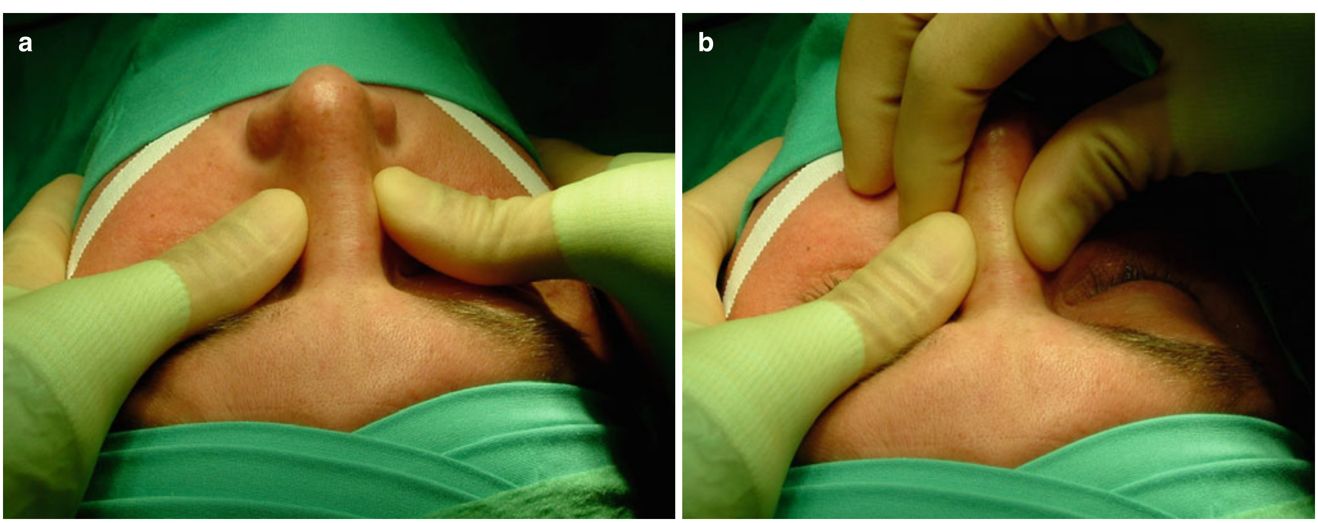

Fig. 10.5 The nasal bones are gently manipulated and aligned (**a**, **b**)

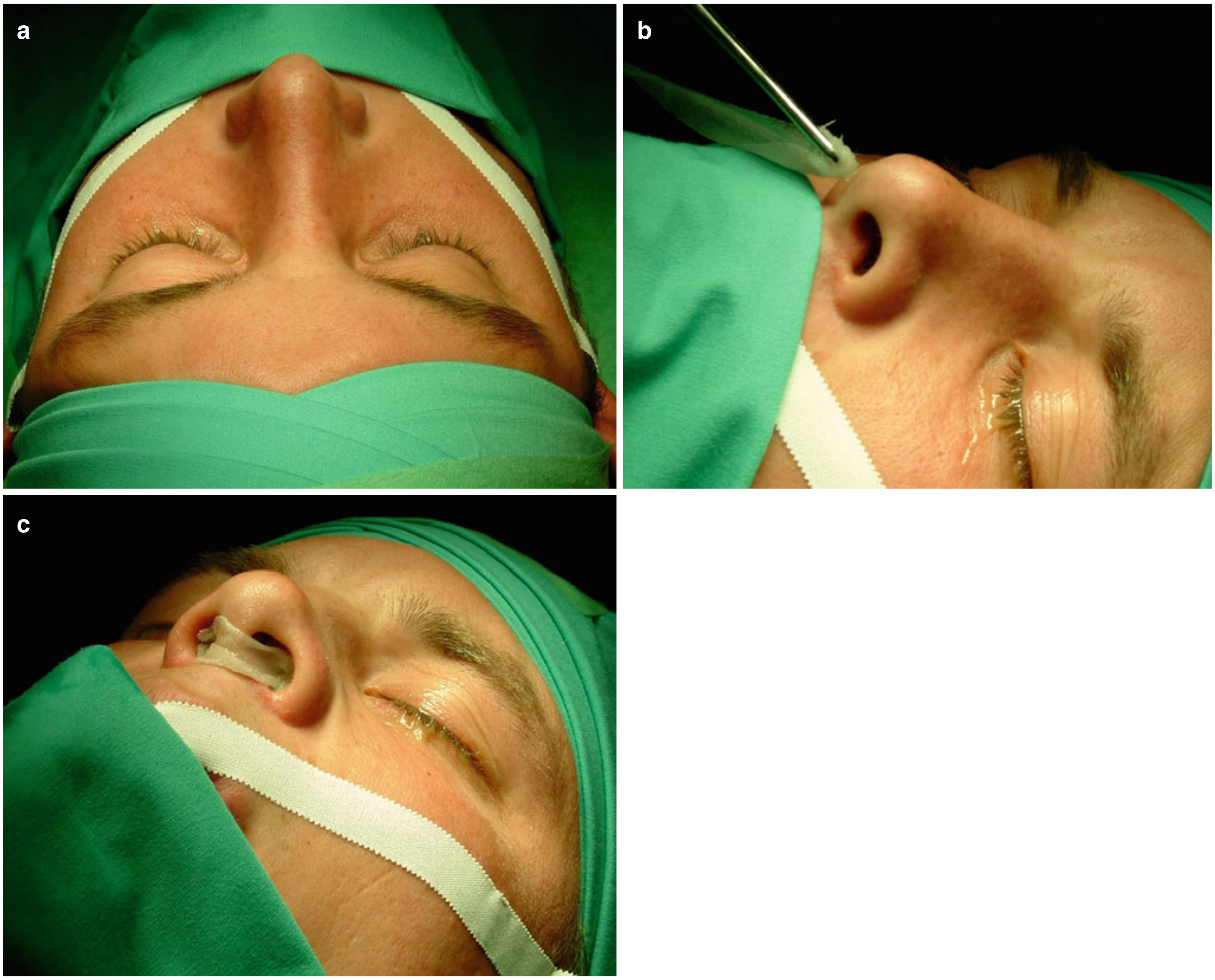

Fig. 10.6 Final alignment and light packing for haemostasis (**a**, **b**)

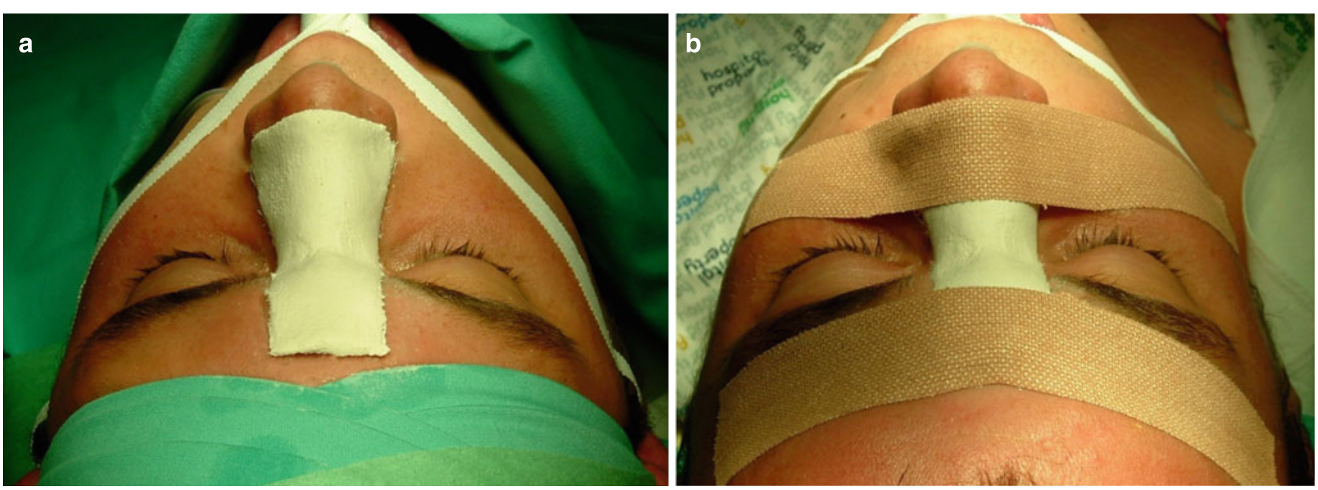

Fig. 10.7 POP cast placed over Steri-Strips (**a**) and supported with adhesive elastic tape (**b**)

Wet plaster of paris (POP) is a caustic solution ($2CaSO_4.2H_2O$) and highly irritant to the eyes if it comes into contact. It also produces heat on setting. For this reason, preparing and placing a POP nasal splint requires a number of precautions, not only to get a good-quality cast, but also to protect the eyes (*see* Figs. 10.8, 10.9 and 10.10).

1. Protect the eyes (use plenty of protective eye ointment and tape them shut; *see* Chap. 18).
2. To ensure a good-quality cast, the dry POP slab needs to be initially soaked for a few seconds (until all the air bubbles have been released). A quick dip does not allow the water to penetrate throughout all the layers, and the resulting cast will be weak and fracture. It should therefore be dripping when removed from the water. The excess water needs to be carefully removed to leave a damp, but not dripping plaster, which is then quickly placed. Squeezing it between two large swabs for a few seconds should do this.
3. When placing the plaster, carefully watch for any drops of water that may trickle into the corners of the eyes. These will cause chemical burns.

10.5.1 Plaster of Paris Cast

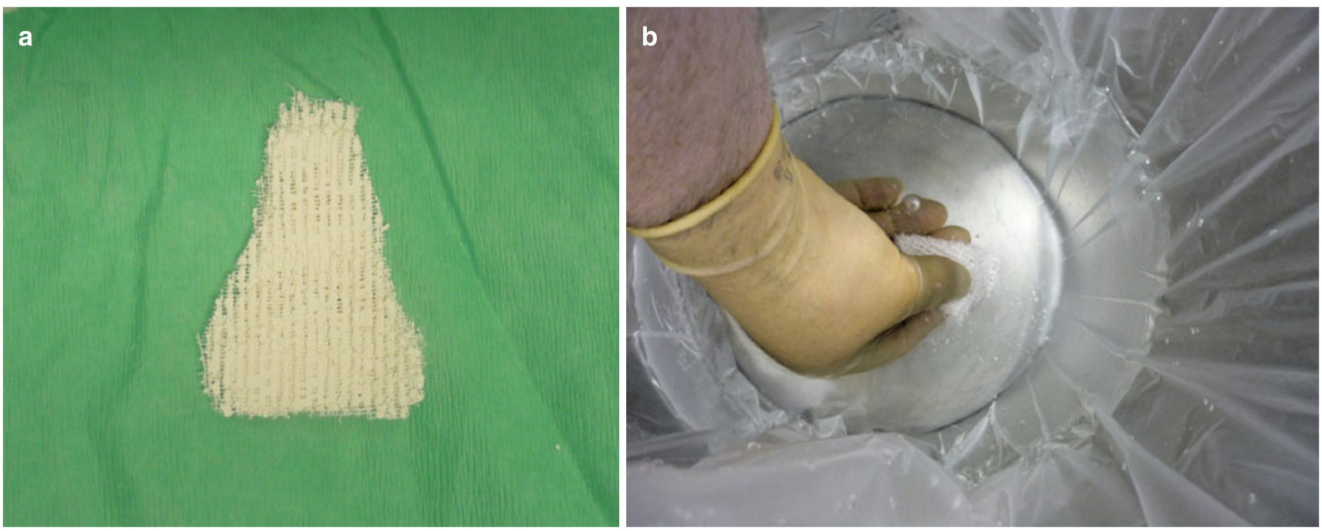

Fig. 10.8 A good plaster cast requires several careful steps. The POP comes as a thin mesh-like bandage impregnated with dry POP (**a**). This is folded into five to ten layers and cut to shape to give a strip several millimetres thick. It is then soaked for several seconds until all the trapped air is released (note bubbles in (**b**))

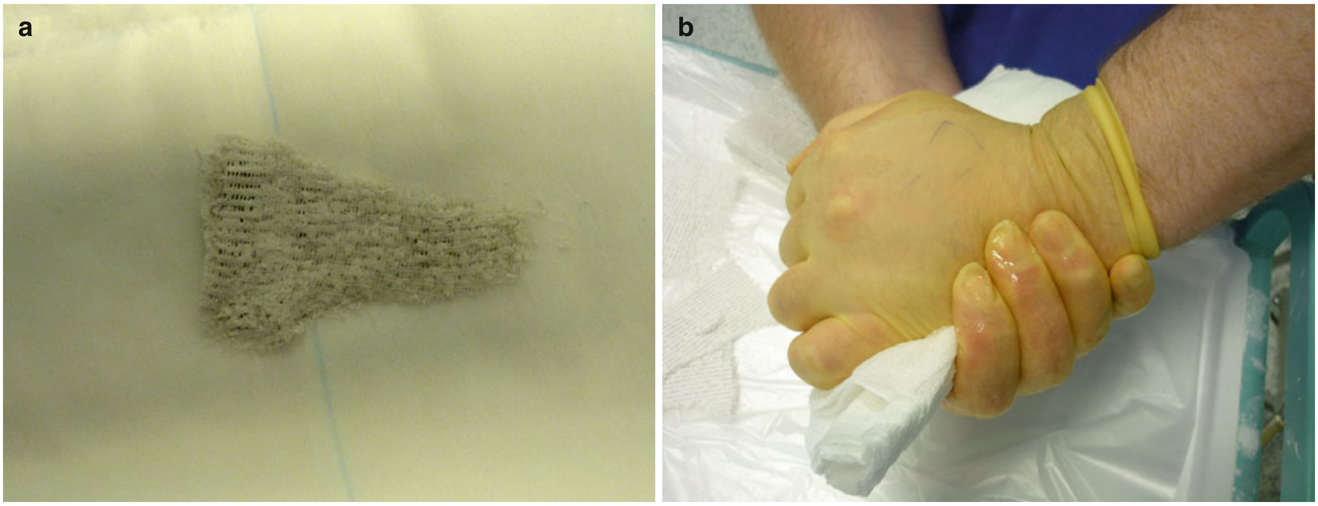

Fig. 10.9 The soaking plaster (**a**) is then squeezed between two gauze swabs to remove excess water (**b**). It should not be dripping wet

Fig. 10.10 Common mistakes are failure to soak the plaster long enough, or failure to remove the excess water. Both will result in a weakened cast. The warmer the water, the quicker the plaster sets

10.5.2 Impression Compound Cast (Thermoplastic)

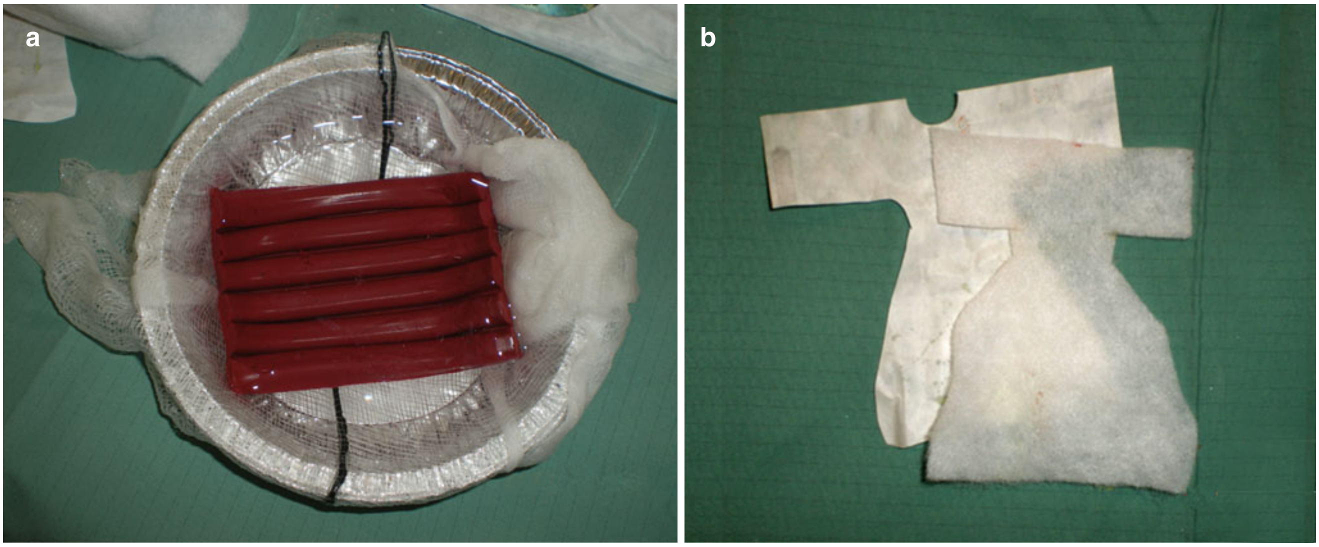

Fig. 10.11 This needs to be soaked in water at 55–60 °C (**a**). A template and dressing are cut (**b**)

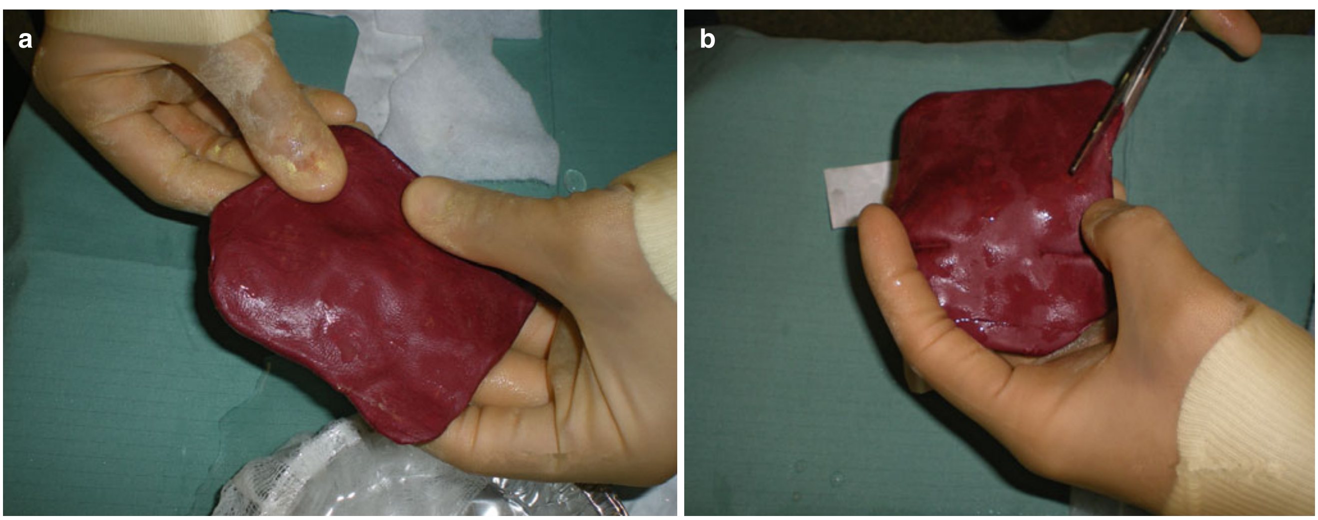

Fig. 10.12 When the material is soft enough it is gently teased out to a sheet several millimeters thick and cut to shape (**a**, **b**)

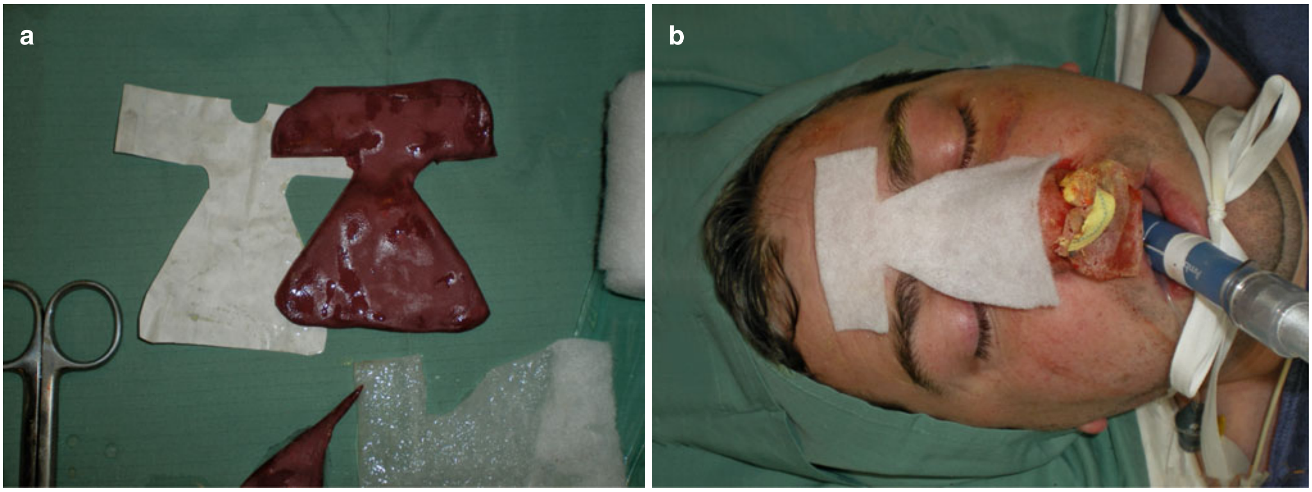

Fig. 10.13 Trimmed material and nonadhesive dry protective dressing (**a**, **b**)

Fig. 10.14 The compound is gently shaped to the nose, which has been previously lightly packed (**a**, **b**)

Fig. 10.15 Splint is supported with tape

10.5.3 Manipulation Using Instrumentation

If the nasal bones have been displaced medially, it may be necessary to reposition them using an instrument (*see* Fig. 10.16). Traditionally, a large pair of scissors is often used, but this is not to be encouraged.

Walsham forceps allow a more precise manipulation of the bones. They come in pairs and are designed to gently grip the nasal bones, allowing three-dimensional control of movement. Care is required as these can crush the soft tissues if gripped too tightly. Therefore protect the skin if these are used (*see* Figs. 10.17 and 10.18).

Once the bones have been manipulated, the septum must be carefully assessed for alignment and any tears in the mucosa. If deviated, the septum can be straightened using Ashes forceps. These are specially designed so that when the handle is gripped tightly, the blades of the forceps remain separated by a few millimeters and therefore do not crush the septum. Using these forceps, the septum can be firmly gripped (but not crushed) and then manipulated (remembering that in some patients septal deviation may have existed before injury) (*see* Figs. 10.19 and 10.20).

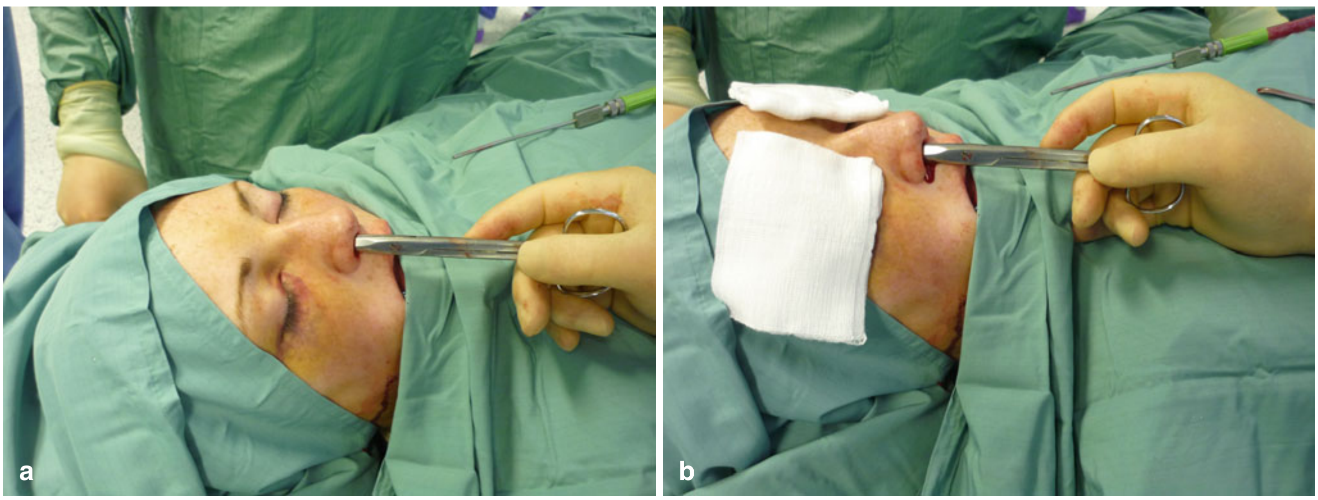

Fig. 10.16 (**a**, **b**) Repositioning of isolated collapsed right nasal bone fractures following localised injury. In this case, blunt-ended scissors were used. The left nasal bones were not fractured. These injuries require gentle packing (one side only) and an external splint to support the mobile bones

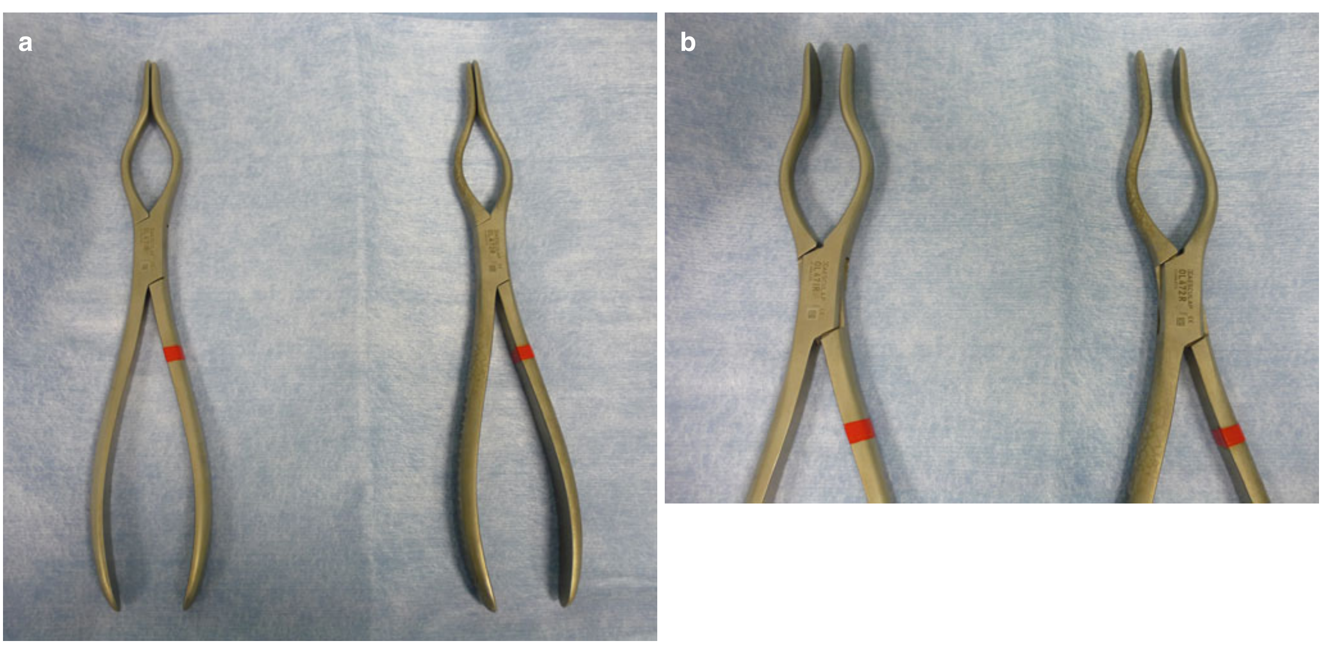

Fig. 10.17 Right and left Walsham forceps (**a**). Look closely: the beaks are different—one is rounded, the other more flat (**b**)

Fig. 10.18 Manipulation of nasal bones with Walsham forceps (**a**–**d**). The round beak passes into the nose, the flatter beak alongside it. These are designed to grip the nasal bones through the skin and mucosa. The outer beak has soft rubber tubing over it to prevent crushing of the skin. Always clean and look up the nasal cavity before passing these—they can cause damage if forced

Fig. 10.19 Ashes forceps (**a**, **b**). Unlike Walsham forceps, the beaks are the same. These are designed to hold the septum without crushing it

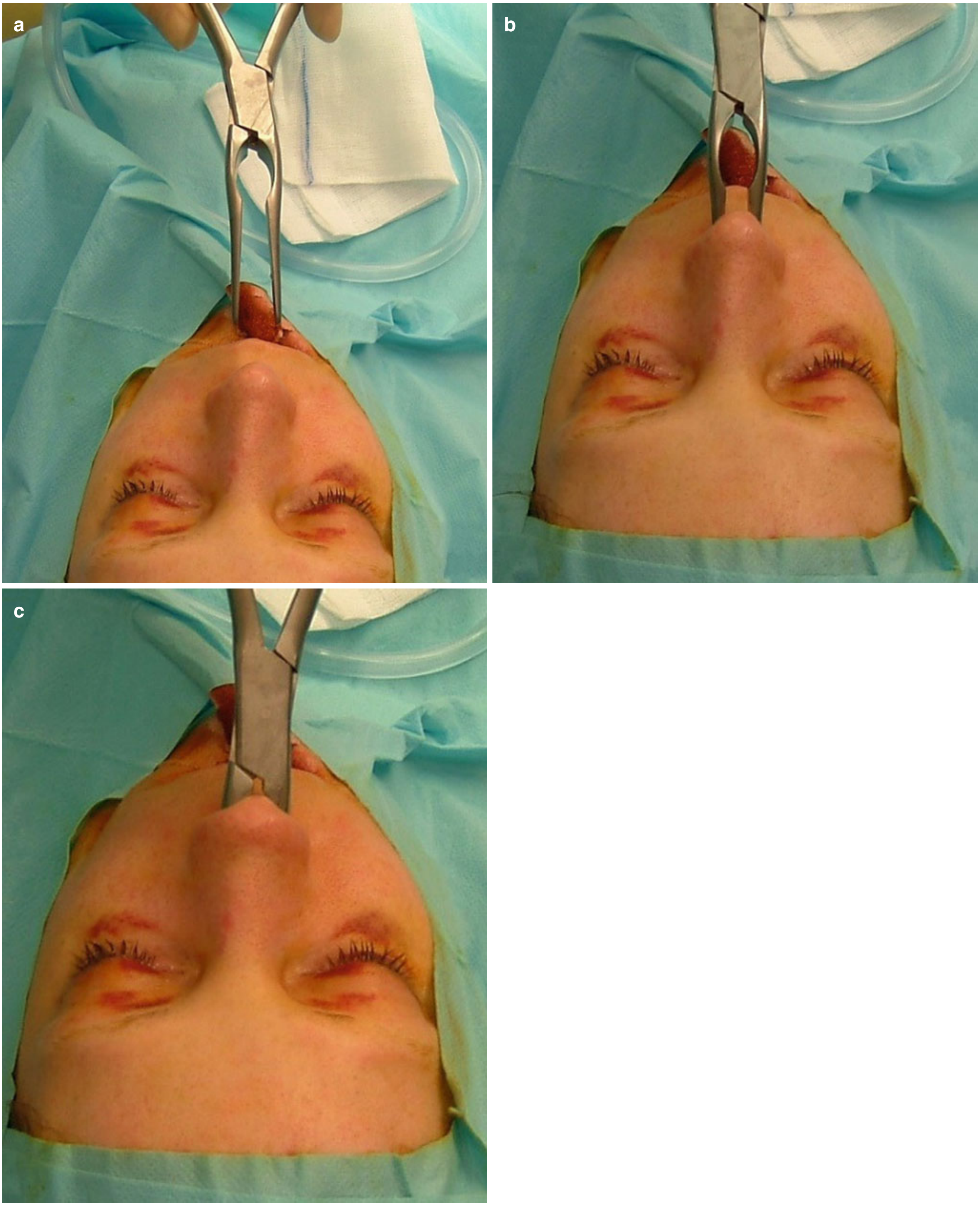

Fig. 10.20 Insertion of Ashes forceps. Gently suck out the nasal cavity first and look at the septum before passing these. Be careful if there are mucosal tears (**a**–**c**)

Nasal bones and the septum should never be forcibly repositioned. Remember that both are closely related to the skull base and medial orbital walls. If a large amount of force is required to move the nose it may be because some of the adjacent bones are still attached and the fracture is not as simple as first thought. Alternatively the patient may have a pre-existing deformity that was not elicited or volunteered from the history.

10.5.4 Comminuted Nasal Fractures

With higher energy injuries both the nasal bones and the septum may be significantly comminuted. These are very difficult fractures to manage with a high incidence of residual deformity.

By way of analogy, the septum is like a tent pole, providing support, projection and preventing collapse of the "tent" (nasal pyramid) to one side (*see* Figs. 10.21 and 10.22). Anatomical reduction of a comminuted septum is virtually impossible and when coupled with comminuted nasal bones a degree of residual deformity and collapse is almost inevitable. For this reason some authorities advocate placing a bone graft along the dorsum of the nose at the time of primary repair. This has the advantage of maintaining the overlying soft tissues close to their original position (thereby minimising contraction), but the disadvantage of a more extensive procedure requiring a second donor site.

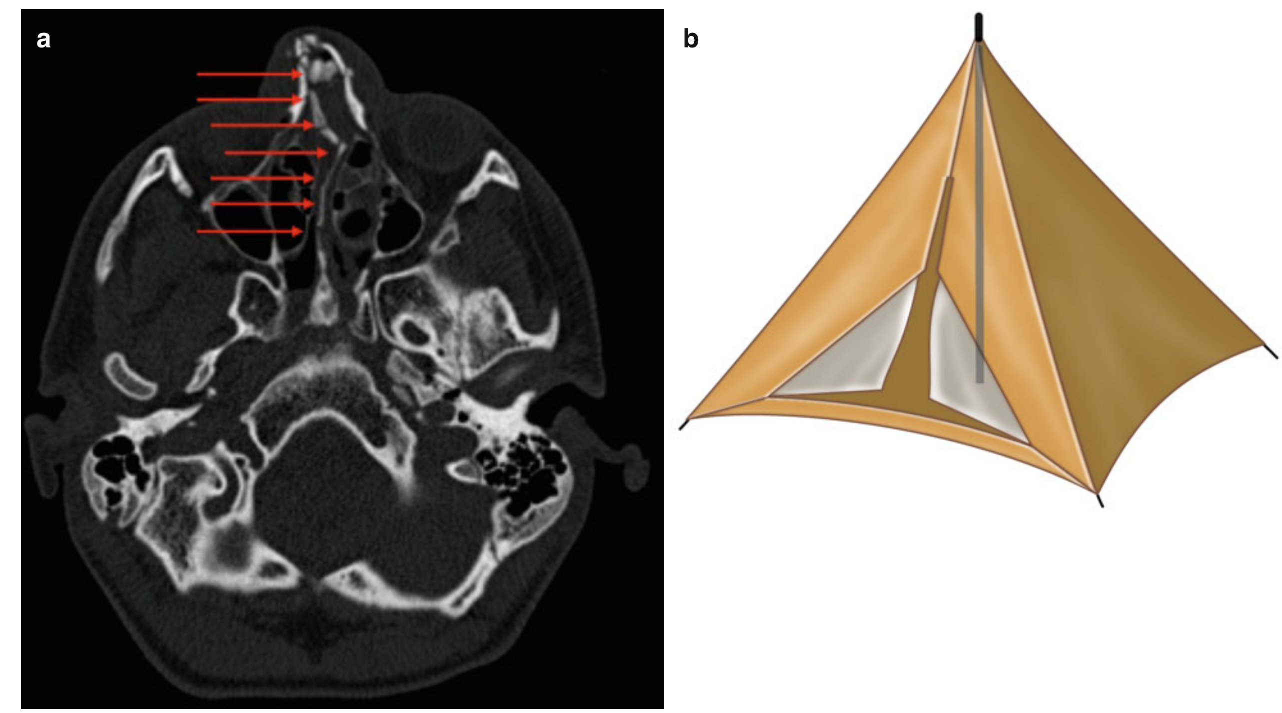

Fig. 10.21 Think of the septum (**a**) like a tent pole (**b**): it maintains projection and stops the "tent" falling over. A severely broken tent pole is a bit of a camping disaster! *Red arrows* show displaced nasal septum

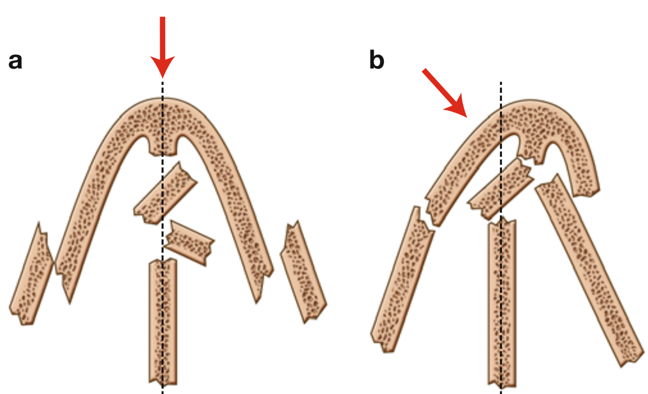

Fig. 10.22 Loss of septal support (**a**) can result in loss of projection or deviation of the nose (**b**). The *arrows* indicate direction of force

Following manipulation of comminuted fractures, plastic splints may be used to support the septum during the healing period. Due to its avascular nature, cartilage usually heals by scar formation rather than producing new cartilage (cf. healing of bone). Splints may therefore be used to support the septum in its correct alignment, in the hope that scarring will maintain favourable support. Splints may also reduce the risk of septal haematoma. These may be sutured (transfixed) to each other, with one splint placed either side of the septum to “sandwich” it prior to packing. However, the evidence for these benefits is mostly anecdotal and some surgeons do not like to use splints at all. Splints may increase the risk of infection and if poorly fitting can ulcerate through the nasal skin and mucosa. They are also uncomfortable to remove.

Nasal packs may also be required for haemostasis, or to support the septum, splints or nasal bones. These come in various form, impregnated with either Vaseline or BIPP (bismuth iodoform paraffin paste). The latter has antiseptic properties and may be preferable if the pack is to remain in situ for more than a few days (*see* Figs. 10.23 and 10.24).

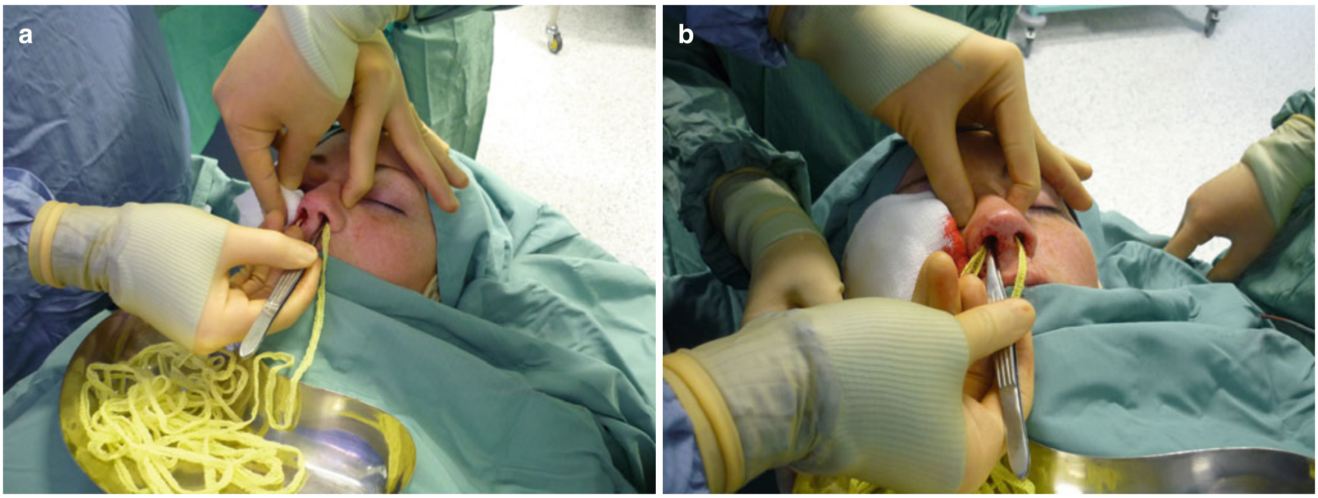

Fig. 10.23 Light nasal packing (in this case using BIPP) (**a**, **b**). Be careful not to overpack; otherwise the nasal bones will drift laterally, resulting in a broad nose

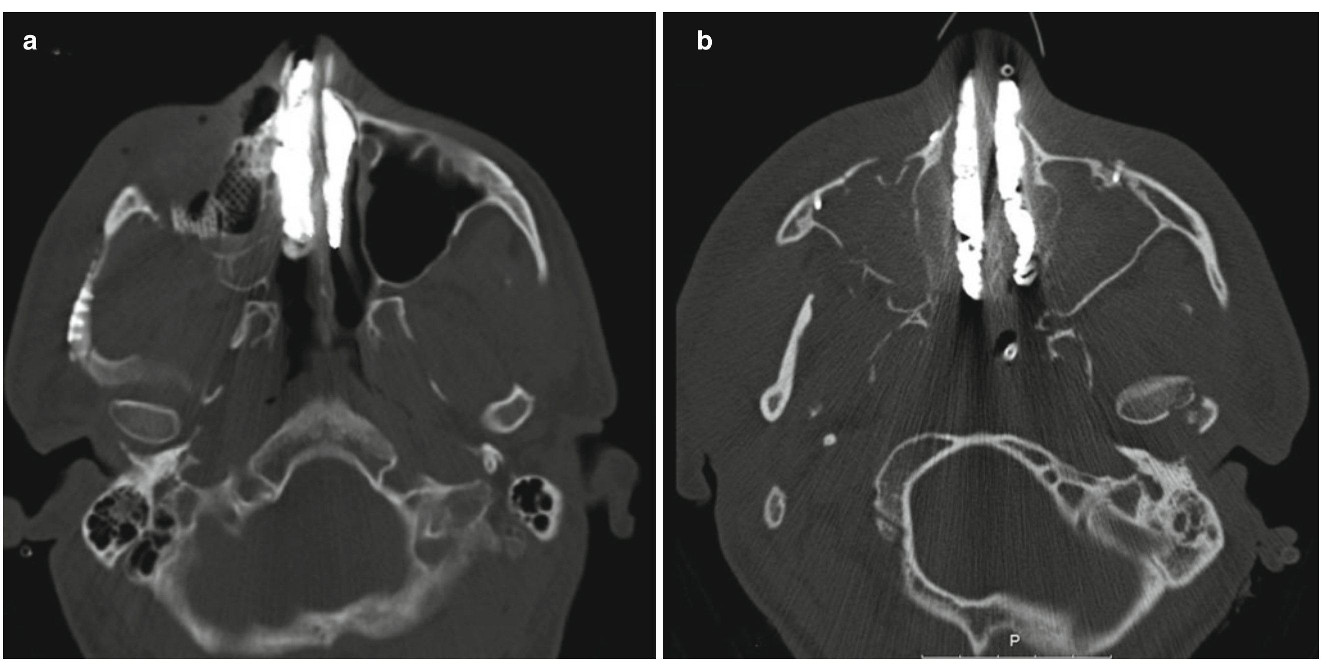

Fig. 10.24 CT showing well-placed BIPP packs supporting the septum and maintaining alignment (**a**, **b**). How long these can stay in is a matter of opinion (risks of infection: *see* text)

Whatever the choice of pack, it must be carefully drained of excess material prior to placement. Vaseline or BIPP in wounds can result in foreign body reactions and excess material can also overspill into the pharynx and be aspirated (*see* Fig. 10.25).

How long a pack stays in situ is a matter of opinion and debate. Working from first principles, the amount of time depends on what it is being used for. For simple haemostasis and to prevent septal haematoma, the pack may only need to stay in situ overnight. When the pack is being used to support comminuted nasal bones or the septum, it may be desirable to leave it in for longer. However, this puts the patient at risk of sinusitis or toxic shock syndrome, so careful risk-benefit analysis is required, weighing up the needs and benefits of

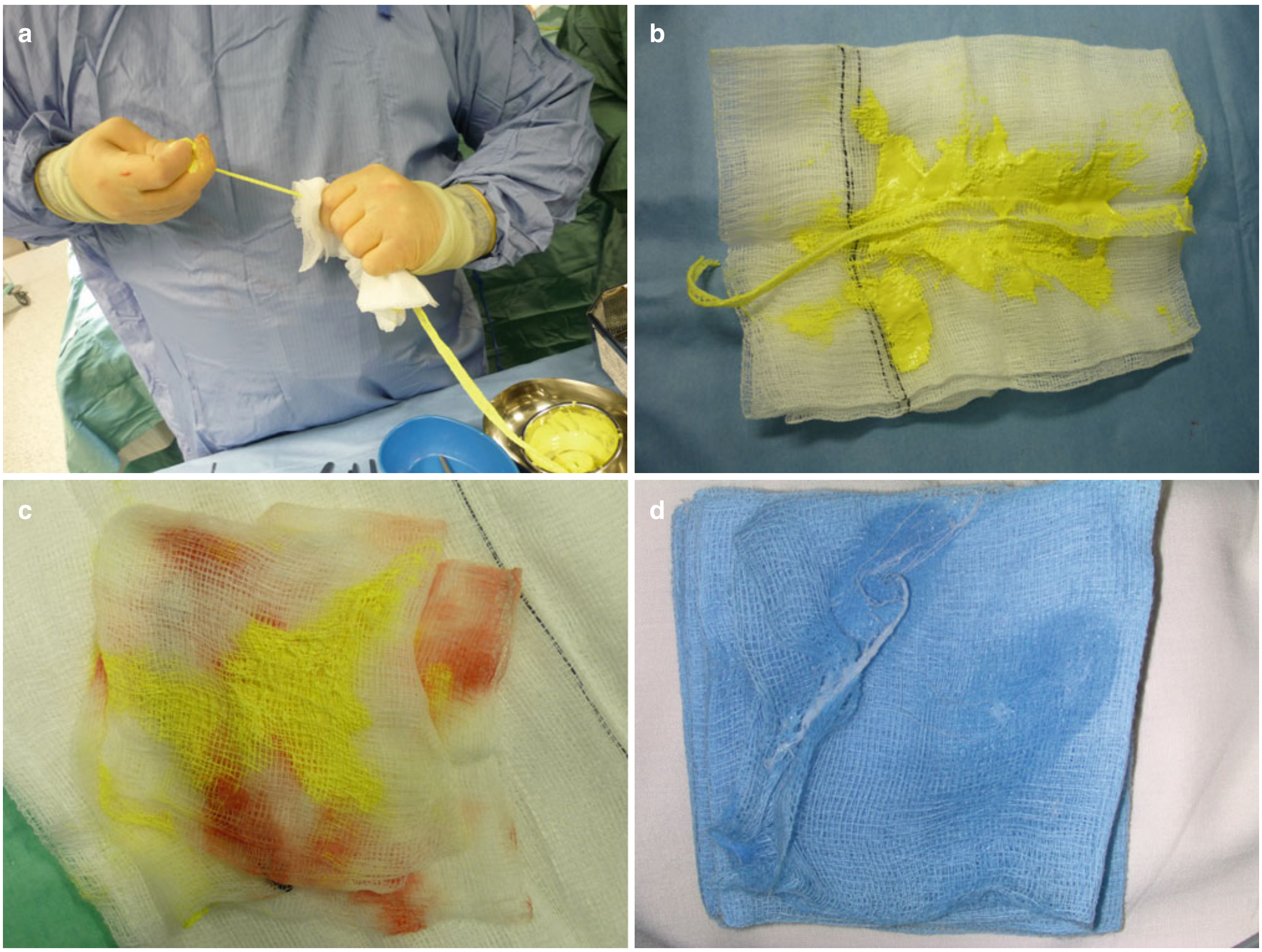

Fig. 10.25 Ribbon gauze can come presoaked in BIPP (or Vaseline) or dry ribbon gauze can be soaked in liquid. Either way, there is usually an excess of liquid that needs to be removed (**a**–**d**). Don't pack a nose with over-soaked gauze. Much of this will end up in the pharynx and there is a risk of aspiration

long-term packing against the risks of infection. If it is decided to leave the pack in situ for more than 24 h, some authorities recommend the use of antibiotics. The patient should also be warned to attend if they develop any symptoms suggestive of infection, for immediate pack removal.

10.5.5 Prolonged External Nasal Support

Not surprisingly, closed manipulation of the nose with external support from a POP splint (or some other material) is an imprecise technique, relying on the surgeon's ability to blindly reposition the bones anatomically. The more comminuted the fractures and the more torn the periosteum, the more difficult this becomes. Furthermore, external nasal splints can often become loose and ill-fitting as swelling resolves and within a few days may provide very little in the way of fracture stability. Together with any collapse of the septum and premature removal of septal splints, it is not surprising that such injuries can result in a broad nasal base, loss of projection, and deviation.

An alternative way of providing longer term external support in such comminuted fractures is shown. This is a difficult procedure but in selected cases can work well. In essence, this involves placement of a large horizontal mattress suture at the base of the nasal bones (pyramid), passing through the fracture sites, which is then used to support an external dressing. If required, the tension on the suture can be readjusted postoperatively. This provides a firmer degree of splintage compared with conventional support and can be left long term until the bones have fully united. Sequencing is important. If the septum has been splinted and the nose needs to be packed, place the pack after passing the suture (so as not to stitch it in). The suture can be adjusted to define the width of the nasal base and tied once packing is complete (overpacking can broaden the nose in comminuted fractures). Skin care is important if prolonged support is required (*see* Figs. 10.26, 10.27, 10.28 and 10.29).

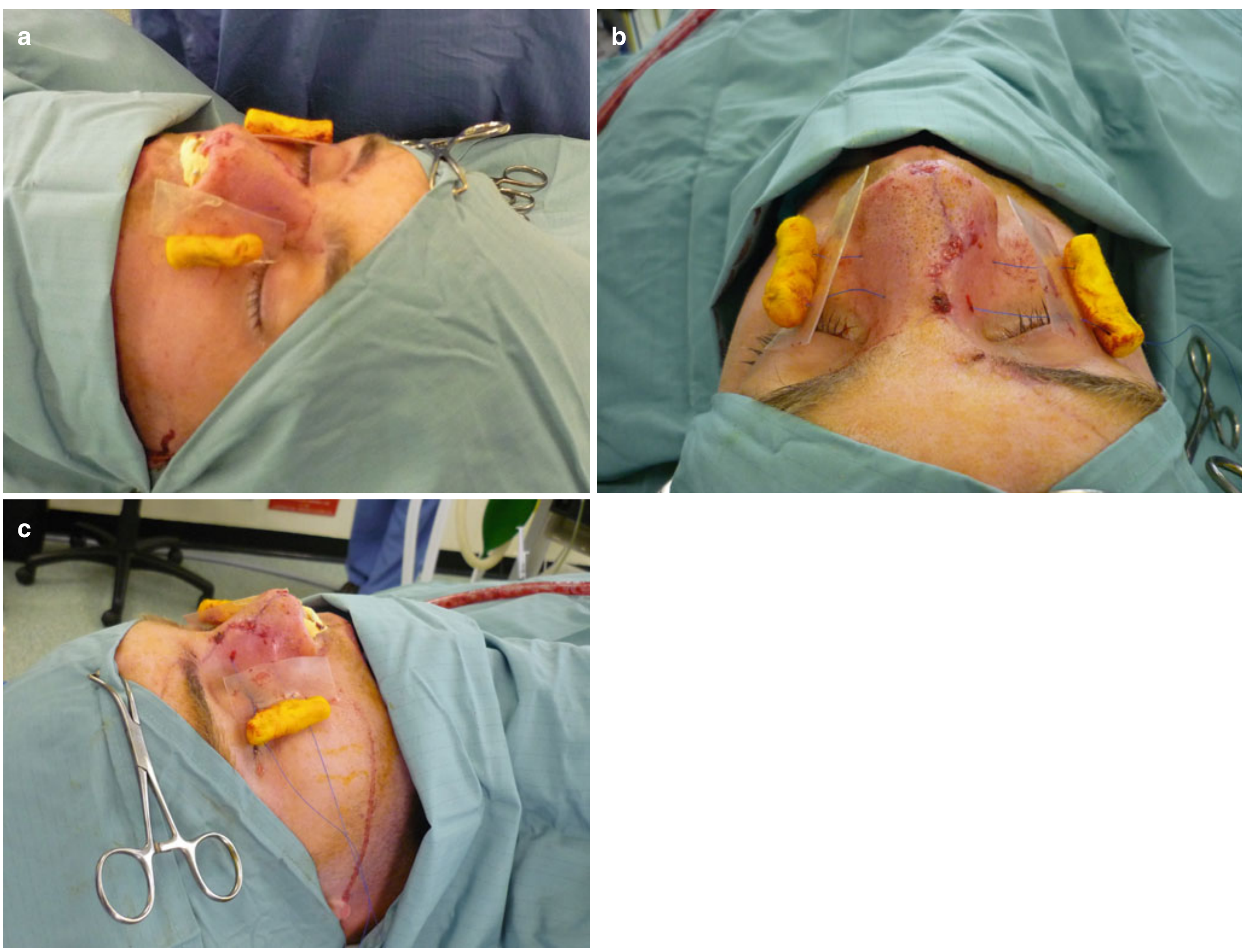

Fig. 10.26 External splints composed of a sheet of silastic and dental rolls soaked in antiseptic (proflavine in this case). A horizontal mattress suture is passed through the fractures and used to secure. This can be used to provide long-term support if needed (**a–c**)

Fig. 10.27 Splint in situ following manipulation of very comminuted nasal fractures (including septum) (**a**–**c**)

Fig. 10.28 Postoperative appearances 1 week (**a**) and 1 month following removal (**b**, **c**)

Fig. 10.29 External nasal splint kept in place for 5 weeks following manipulation of very comminuted nasal bones and septum (**a**, **b**). Postoperative appearance 1 month following removal (**c**, **d**)

10.6 Open Reduction and Internal Fixation of Nasal Bones

Open reduction and internal fixation (ORIF) of nasal bones is a procedure that seems not to have gained the wide acceptance, or popularity as internal fixation of the other bones of the face. This may be for a number of reasons, notably the increased operating time and technicalities of fixing small, thin fragments (particularly when comminuted), and concerns regarding the risks of scars, avascular necrosis, and infection. Nevertheless, in appropriately selected cases this is a very useful technique that has a low complication rate. As such it should be considered whenever there is an overlying laceration (*see* Fig. 10.30).

When attempting to repair complex nasal injuries, a number of important steps must be followed, although the sequence may vary slightly. Due to varying degrees of complexity between cases, each of these steps may need to be addressed to a greater or lesser extent (*see* Table 10.4).

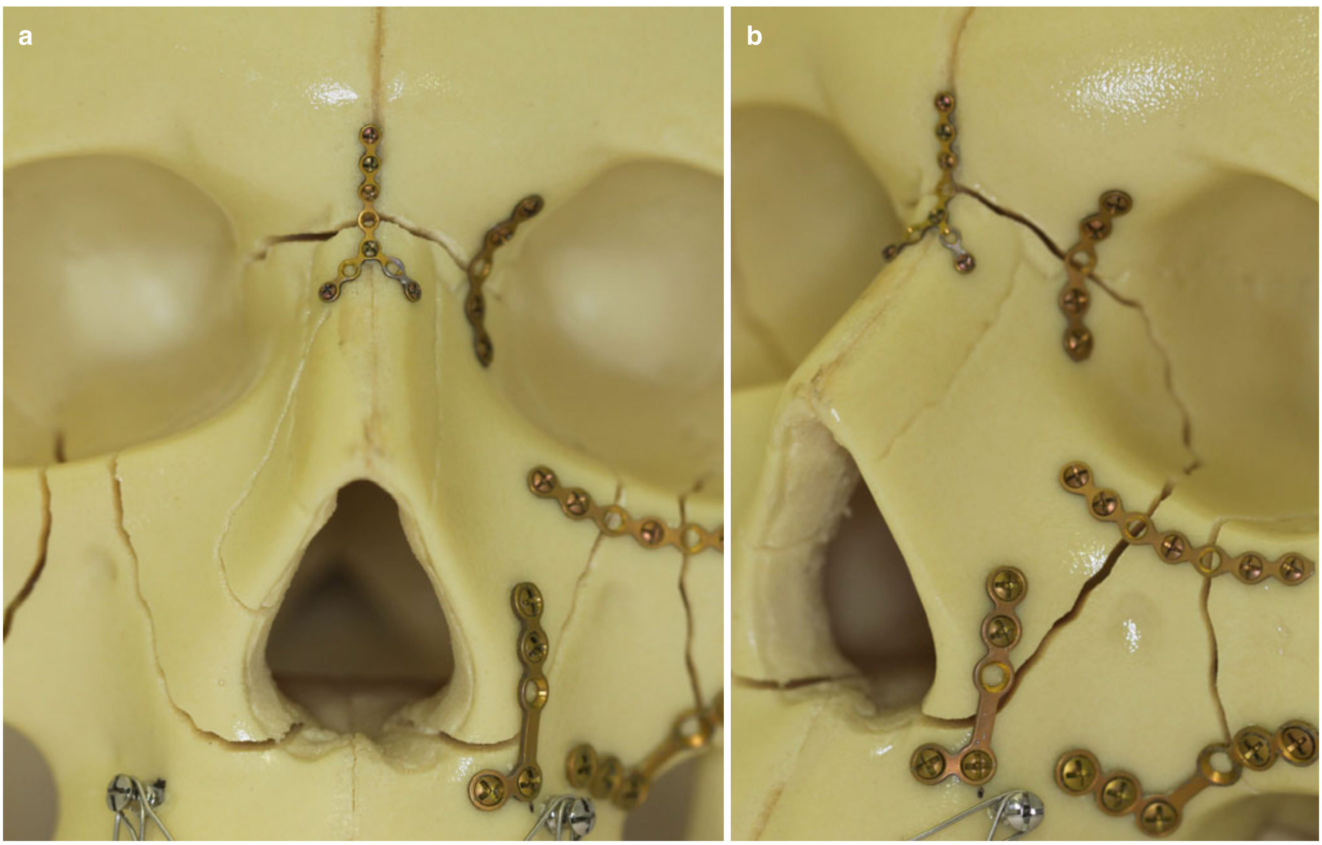

Fig. 10.30 ORIF of nasal bones requires "microplates" about 1 mm thick (**a**, **b**). Screws are 1.3 mm low profile plates and 4 mm screws are used

Table 10.4 Key steps when repairing complex nasal injuries

Make sure you know your nasal anatomy
Septum: realign and reestablish projection
Nasal mucosa: watertight closure
Nasal bones: repair key fractures and those that are large enough to support plates and screws Maintain as much soft tissue attachment as possible
Cartilages: repair obvious tears and reattach upper lateral cartilages to the nasal bones. Consider grafts if cartilage has been lost
External wounds: use these for access. Meticulous debridement, haemostasis, and a layered closure
Consider the need for primary bone grafting (a "dorsal strut")
Consider the need for septal splints and external support

The nasal septum is usually addressed first. Extensive fractures of the nasal septum can result in significant loss of nasal projection and therefore the septum needs to be realigned as best as possible. This may require splints and packs. Although packing is usually undertaken at the end of the procedure, initial alignment and splinting is perhaps best done early, as excessive manipulation following internal fixation may loosen screws or deform the plates.

The lining mucosa needs to be carefully repaired. Ideally all tears should be closed watertight. Hopefully this will reduce the risks of infection.

The external wound must be explored gently, preserving as much attachment to the bone fragments as possible. Periosteal stripping must be kept to a minimum although this needs to be balanced against the need to expose enough bone for fixation. Very small fragments should be left attached to the soft tissues. There is no point in detaching them; all this will achieve is devitalisation.

In some cases (particularly when comminuted), it is not possible to anatomically reduce and fix every fragment of bone. Instead, attention should be paid to those fragments that can be easily and anatomically reduced and are large enough to support a microplate. Sometimes it is easier to secure the microplate to the mobile fragment first before aligning and fixing it to the adjacent bones. Only a few key bones need to be fixed; small fragments can be secured with sutures or adhesives if so required.

With the exception of the nasal bridge, nasal bones are generally quite thin. The choice of screw length is therefore critical. If these are too long they may pierce the underlying mucosa and become exposed to nasal organisms. Typical screw lengths are in the region of 2 or 3 mm. Therefore microplating sets are required for repair.

If the upper lateral nasal cartilages have been detached, these need to be repositioned and secured. This can be done using a suitable suture. If necessary a small hole can be drilled into the bone to allow the suture to be passes. Try to avoid disrupting the junction of these cartilages with the septum. This forms an important valve-like mechanism.

In severely comminuted fractures consider augmenting the nasal dorsum with a bone graft (*see* later).

The wound needs to be closed meticulously in layers, ensuring that the plates and bones are draped in healthy vascularised tissue. The thicker the overlying soft tissues are, the less likely that minor bony irregularities or the plates will be palpable (*see* Figs. 10.31–10.44).

Case 1

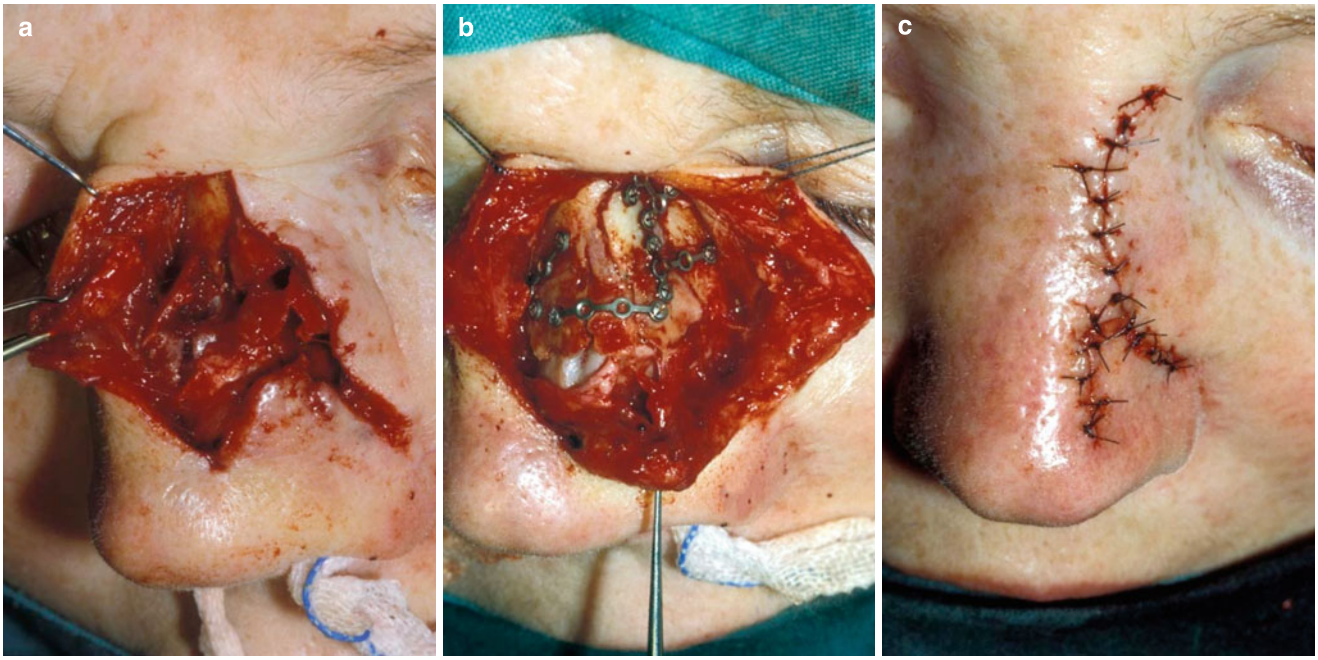

Fig. 10.31 ORIF of nasal fractures through an overlying laceration (patient was hit by a brick). Septum fractured but not comminuted (**a**–**c**)

Case 2

Fig. 10.32 Comminuted nasal bones

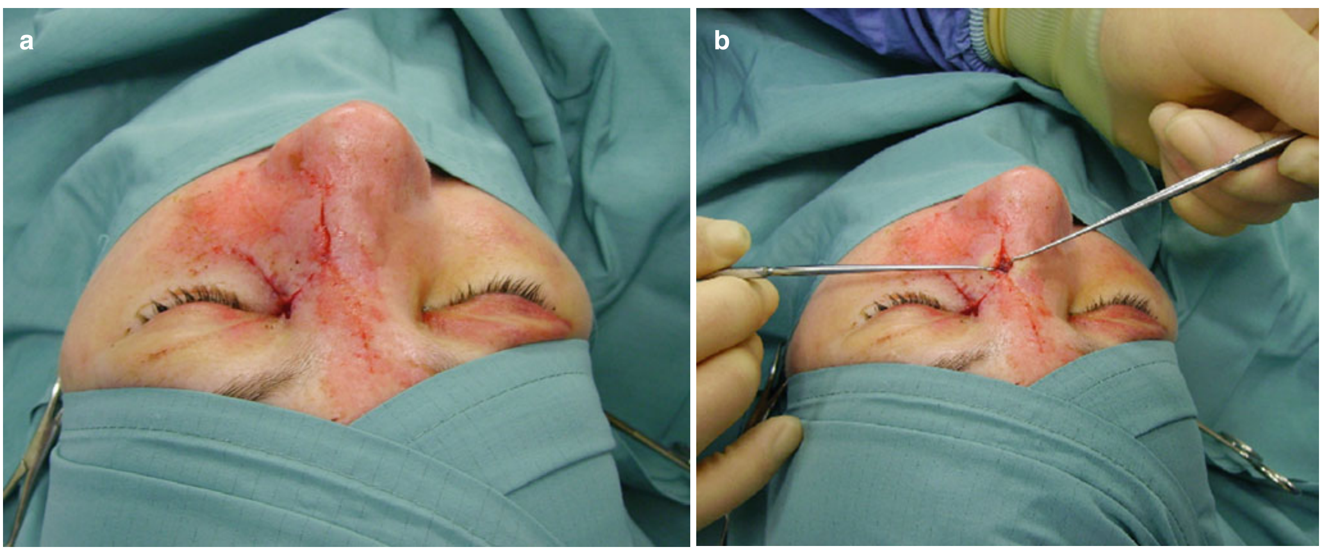

Fig. 10.33 A deceptive injury. Initial appearances (**a**, **b**) failed to show the true extent of the injury

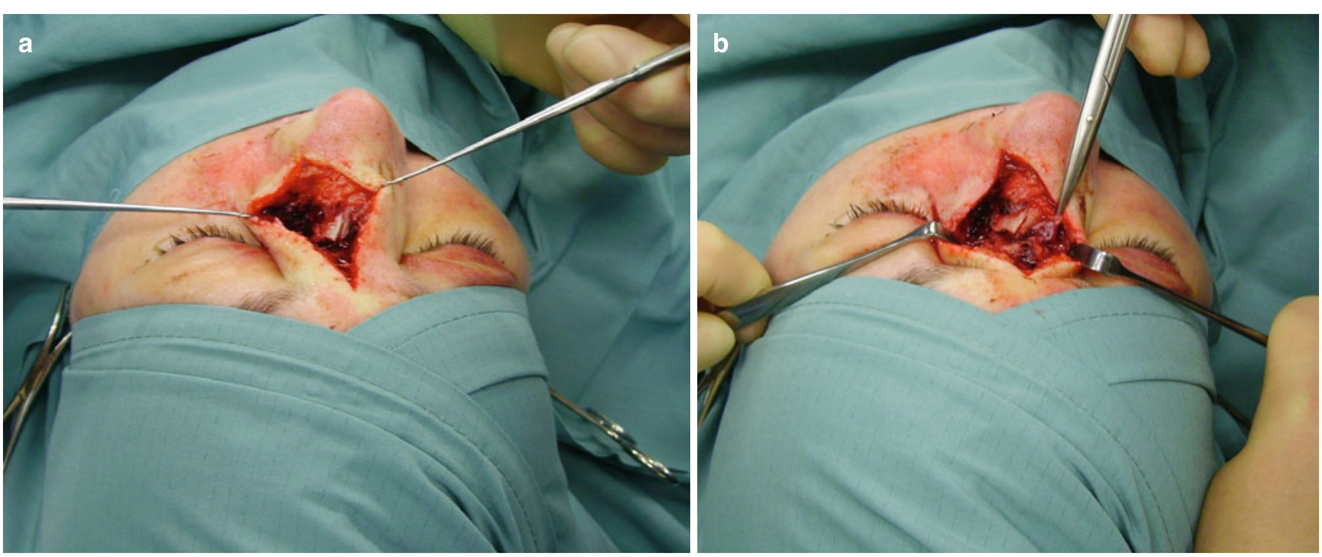

Fig. 10.34 Once the laceration has been fully opened, the true extent of the injury is seen (**a**, **b**)

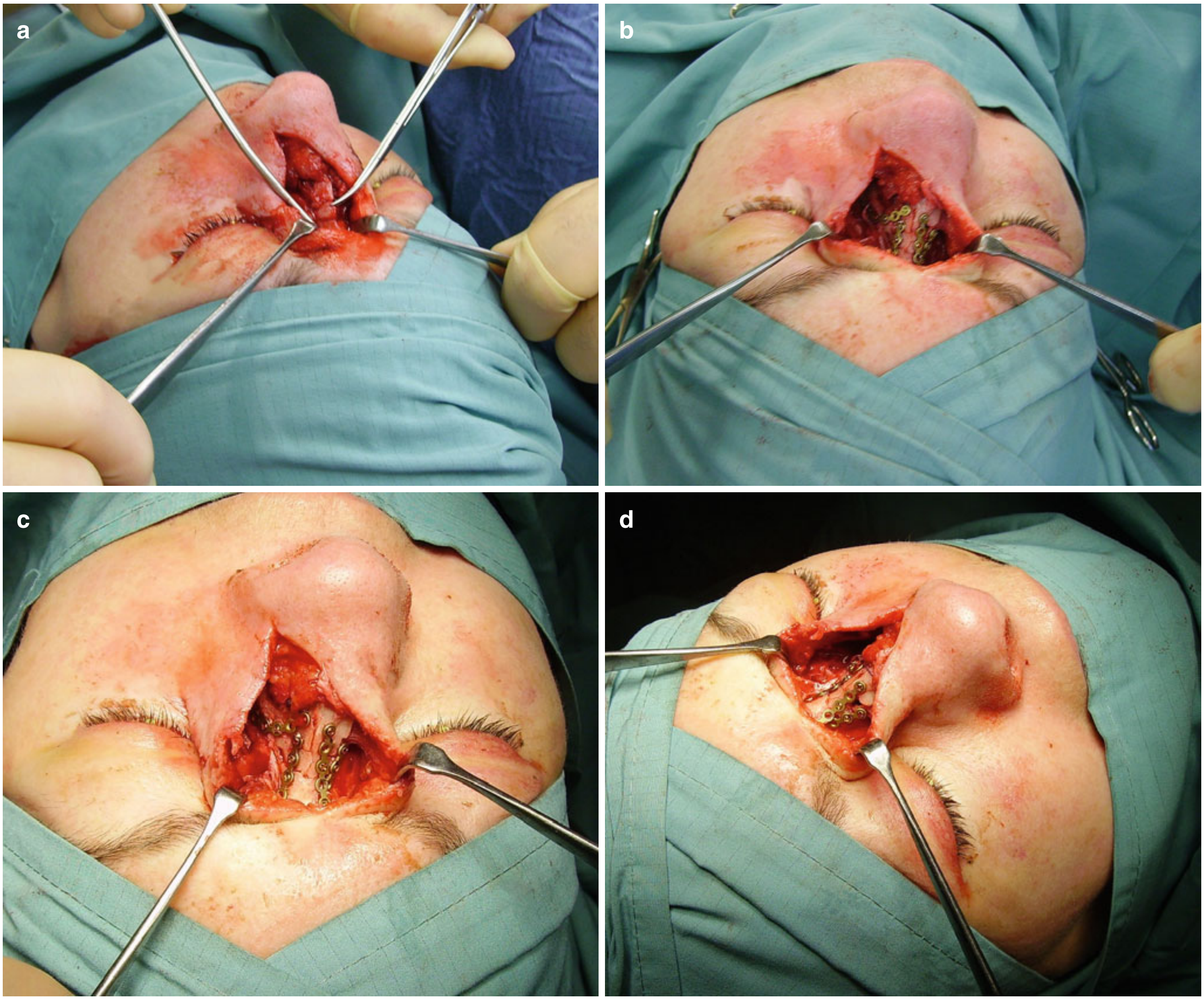

Fig. 10.35 Repositioning and repair of fractures using 1.2-mm plates (**a–d**)

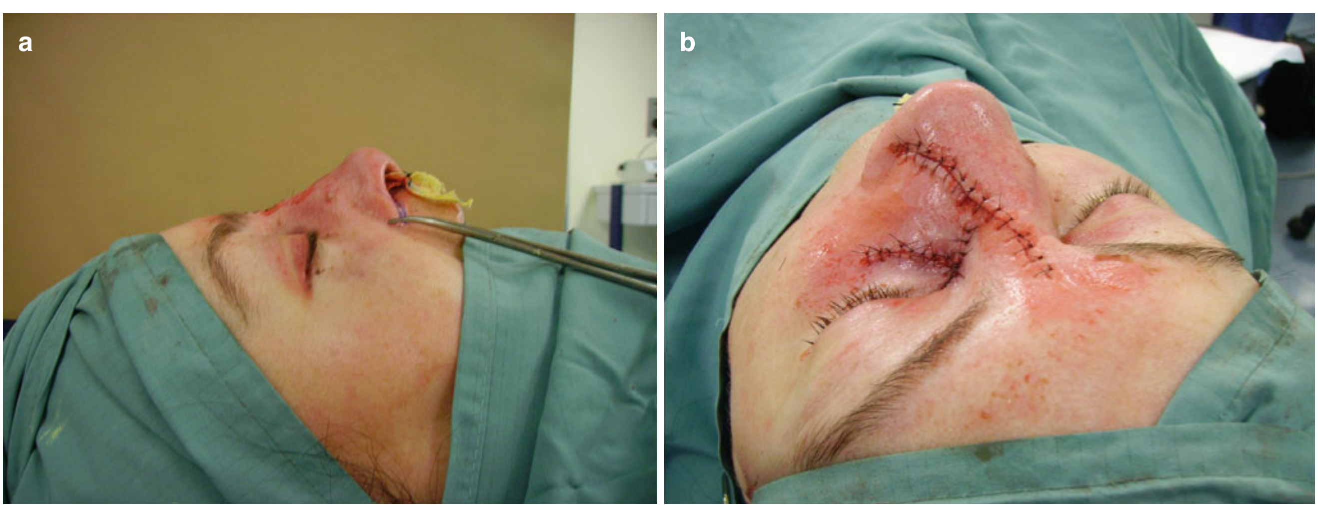

Fig. 10.36 Satisfactory nasal projection and closure of the laceration in layers (**a**, **b**)

Case 3

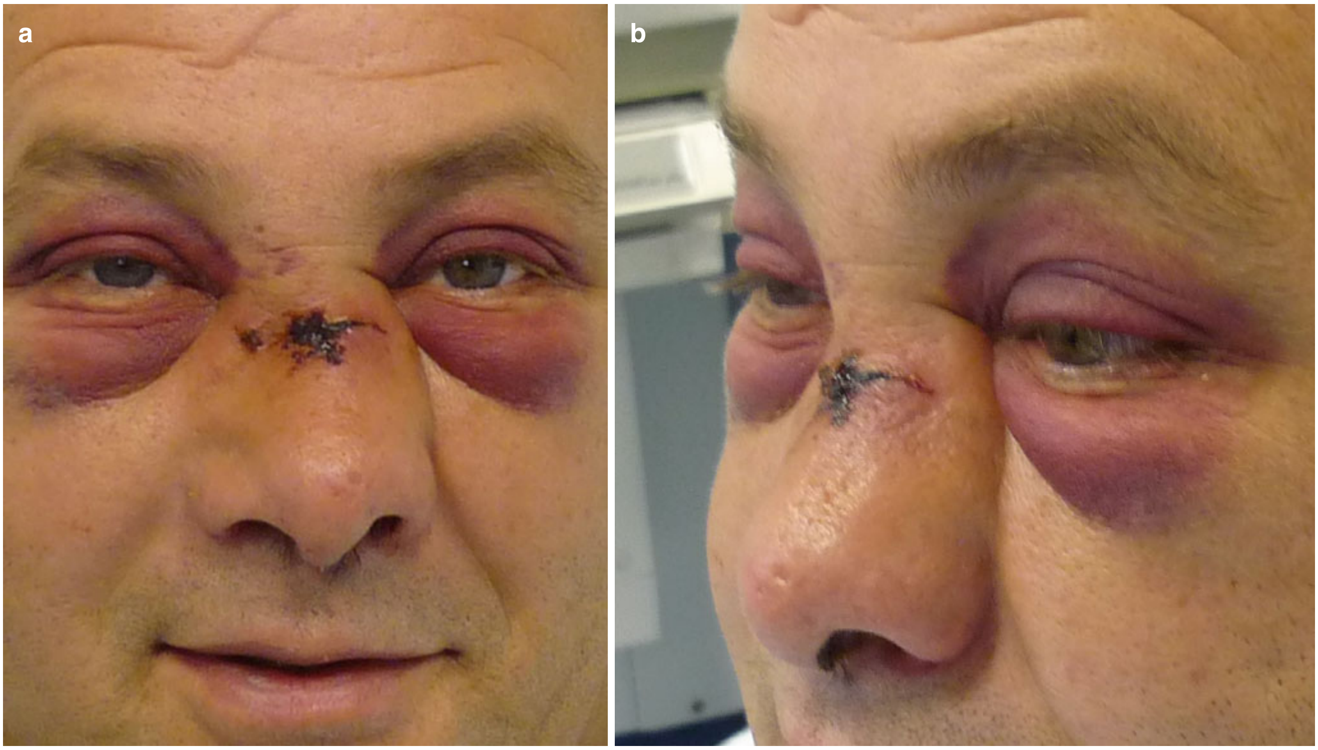

Fig. 10.37 Gross nasal deviation and small laceration following localised blow with a projectile (**a**, **b**)

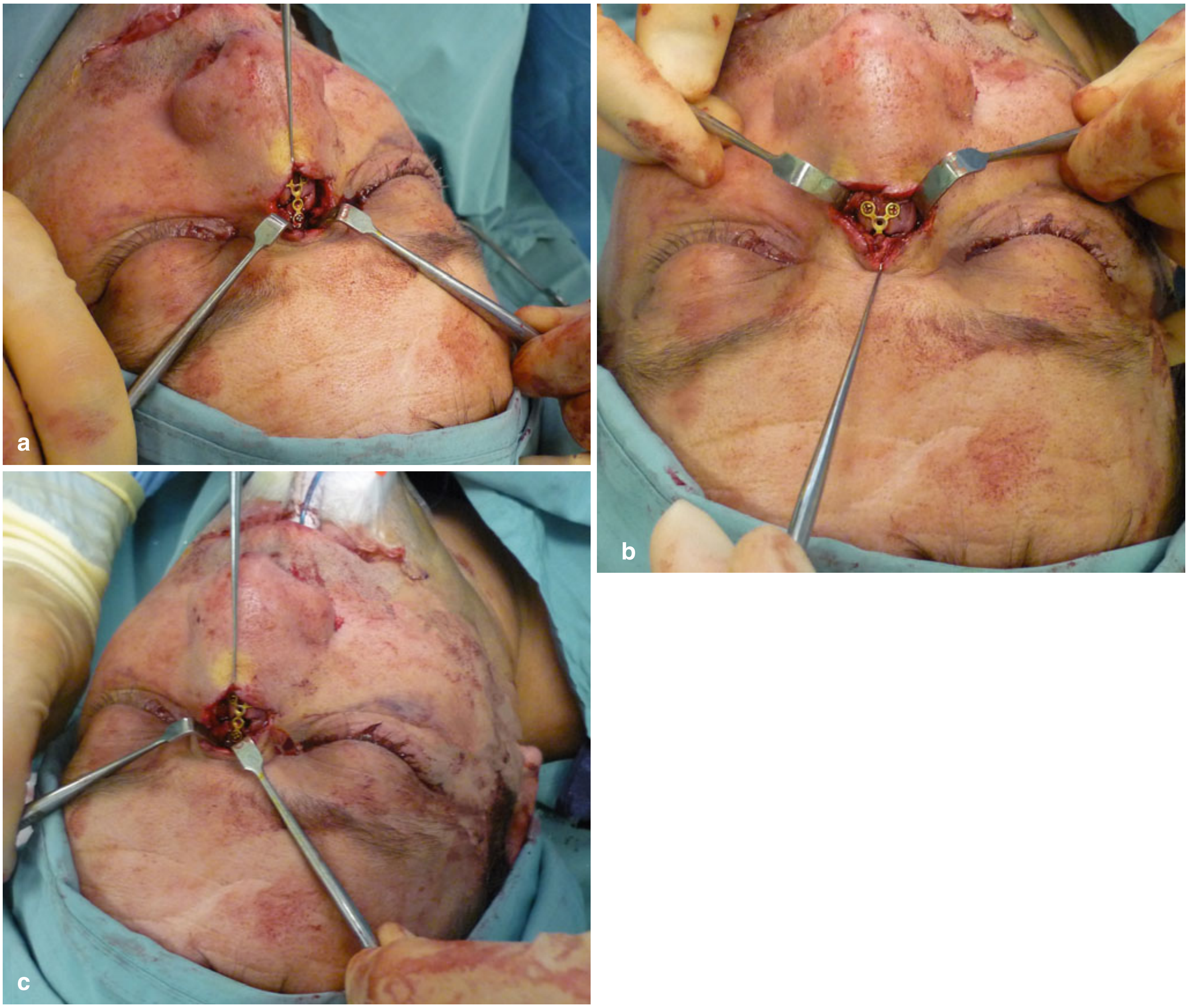

Fig. 10.38 Exploration and repair through laceration (**a**–**c**)

Fig. 10.39 Wound closure and satisfactory nasal projection (**a**, **b**)

Fig. 10.40 Post operative appearances at 1 week (septal splints in place) (**a**, **b**)

Case 4

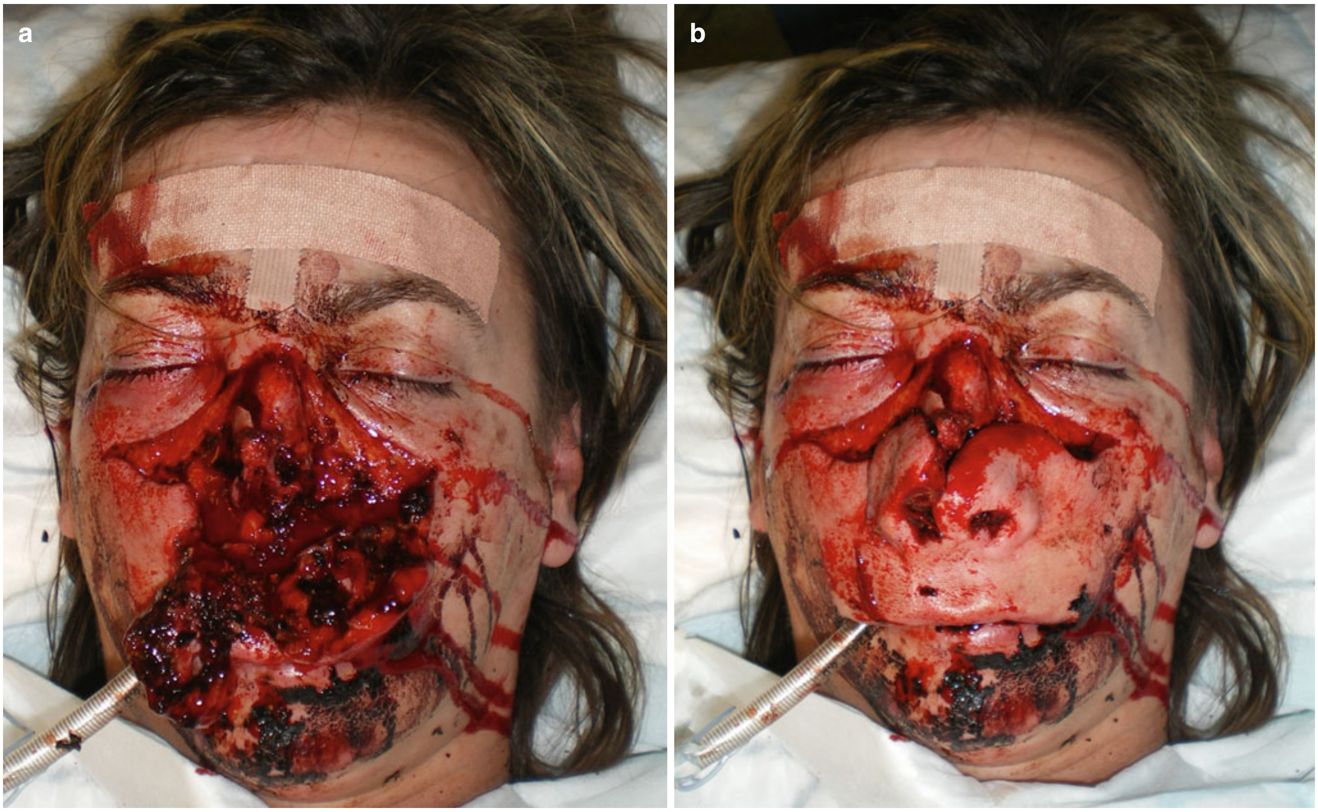

Fig. 10.41 Extensive and complex nasal injuries following a fall from a bicycle (**a**, **b**)

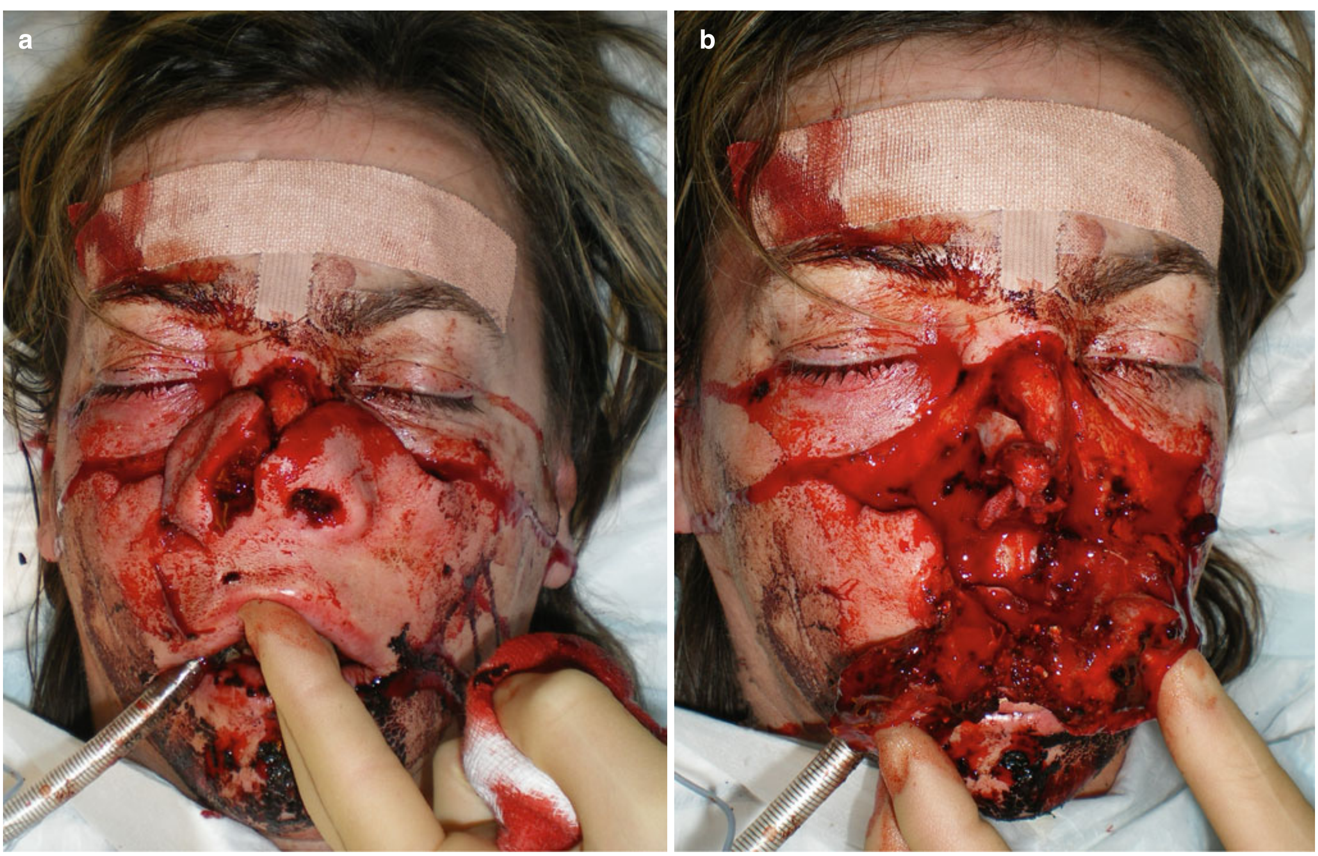

Fig. 10.42 Examination under anaesthesia (**a**, **b**)

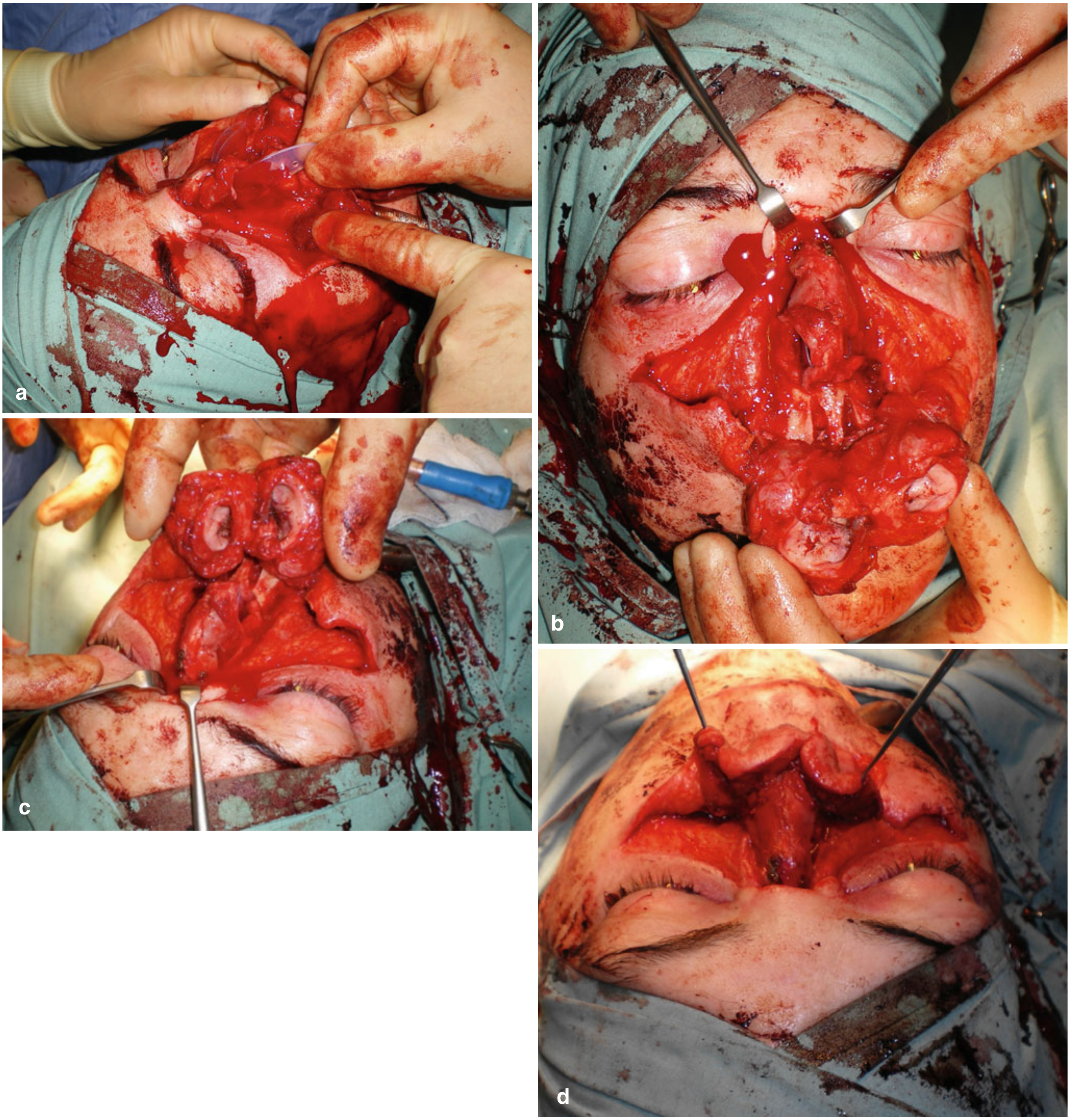

Fig. 10.43 Repair (*see* Table 10.4 for sequencing) (**a**–**d**)

Fig. 10.44 Final closure. In this case no bone graft was used (**a**, **b**)

10.7 Augmentation of the Nasal Bridge

Realistically it is not possible to restore full nasal projection in every case, particularly when there has been extensive damage. While some of the above techniques may minimise collapse of the nose and loss of projection, a degree of both is inevitable in most cases. When this is felt likely to occur, placement of an onlay bone graft may maintain a degree of projection. Cortical bone may be harvested from one of a number of sites and fashioned into a lens-shaped strut, which is then secured over the comminuted bones along the dorsum of the nose. This helps maintain support and projection of the "soft tissue envelope" (overlying soft tissues) thereby minimising residual deformity and making subsequent correction much easier. Surprisingly good results are possible in some cases (*see* Figs. 10.45 and 10.46).

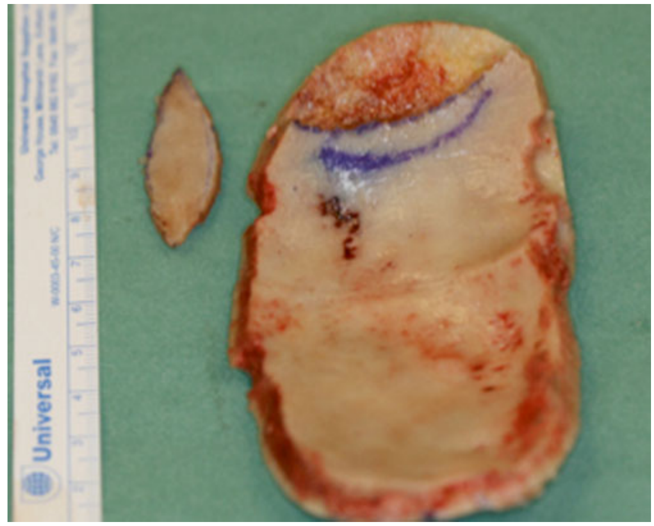

Fig. 10.45 Nasal strut harvested from calvarial bone (patient required a craniotomy)

Case 1

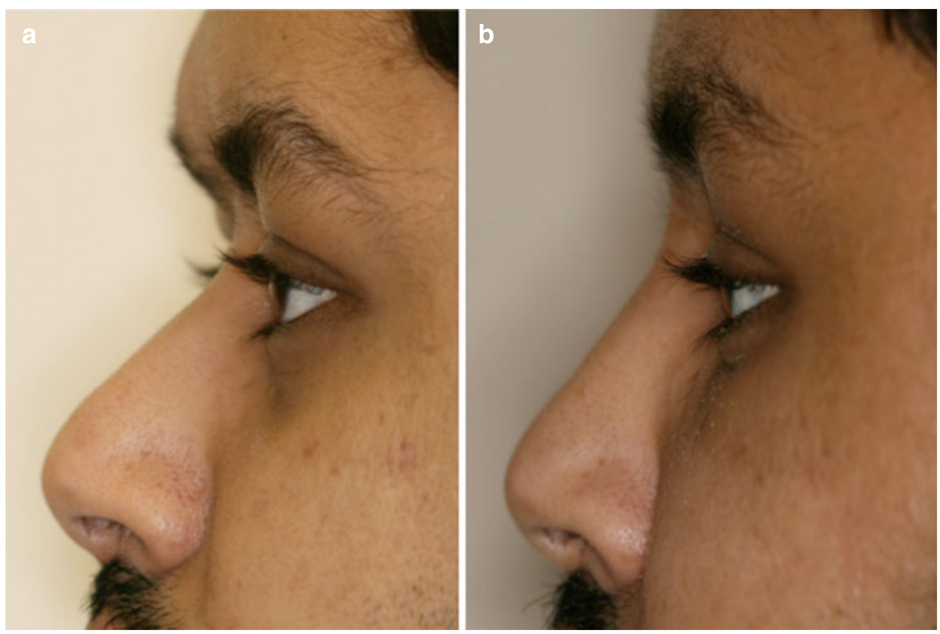

Fig. 10.46 Augmentation nasal bridge using bone graft (**a**, **b**)

Placing an onlay graft at the time of primary repair may avoid secondary surgery, by preventing the soft tissue envelope from contracting. This would make subsequent reconstruction difficult. However, this requires a free nonvascularised graft and as such is at risk of necrosis and infection. The decision to place a graft at the time of primary repair therefore depends on a number of factors—the more compromised the overlaying soft tissues the greater the risk of graft failure. Ideally rigid fixation should be undertaken to facilitate take of the graft (*see* Fig. 10.48).

Case 2

Fig. 10.47 (**a**–**c**) Severe facial injuries with extensively comminuted nasal bones. Primary bone grafting using calvarial bone maintained satisfactory nasal projection

Case 3

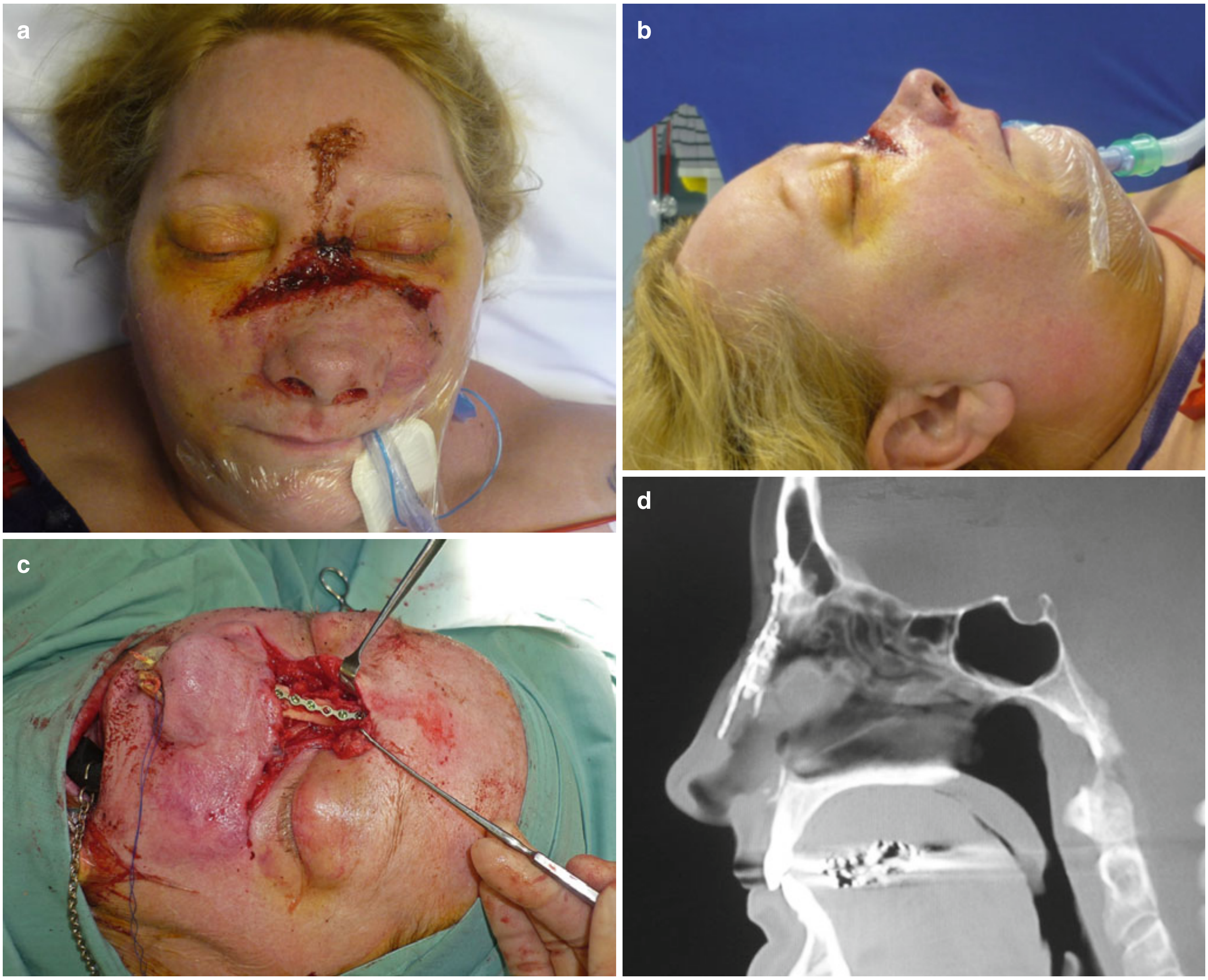

Fig. 10.48 Severely comminuted nasal bones and septum following a fall (face first) onto a concrete step. Bone grafting at time of primary repair in an attempt to minimise secondary deformity (**a**–**d**). This requires careful follow up and aftercare. The soft tissue over the graft is quite thin (seen on CT). Further correction will be likely

10.7.1 Should We Make Elective Incisions?

Opinions are divided on this. The nose is unique in that it seems to be the only bone in the face where there is some reluctance to incise the overlaying skin and fix it following trauma or an osteotomy (i.e., rhinoplasty). Understandably, concerns focus on the risks of plate infection and unsightly scarring although (anecdotally) these are, in fact, quite low. However, since the evidence base for this is lacking, the final decision is largely a matter of personal preference (*see* Figs. 10.49, 10.50 and 10.51).

Case 1

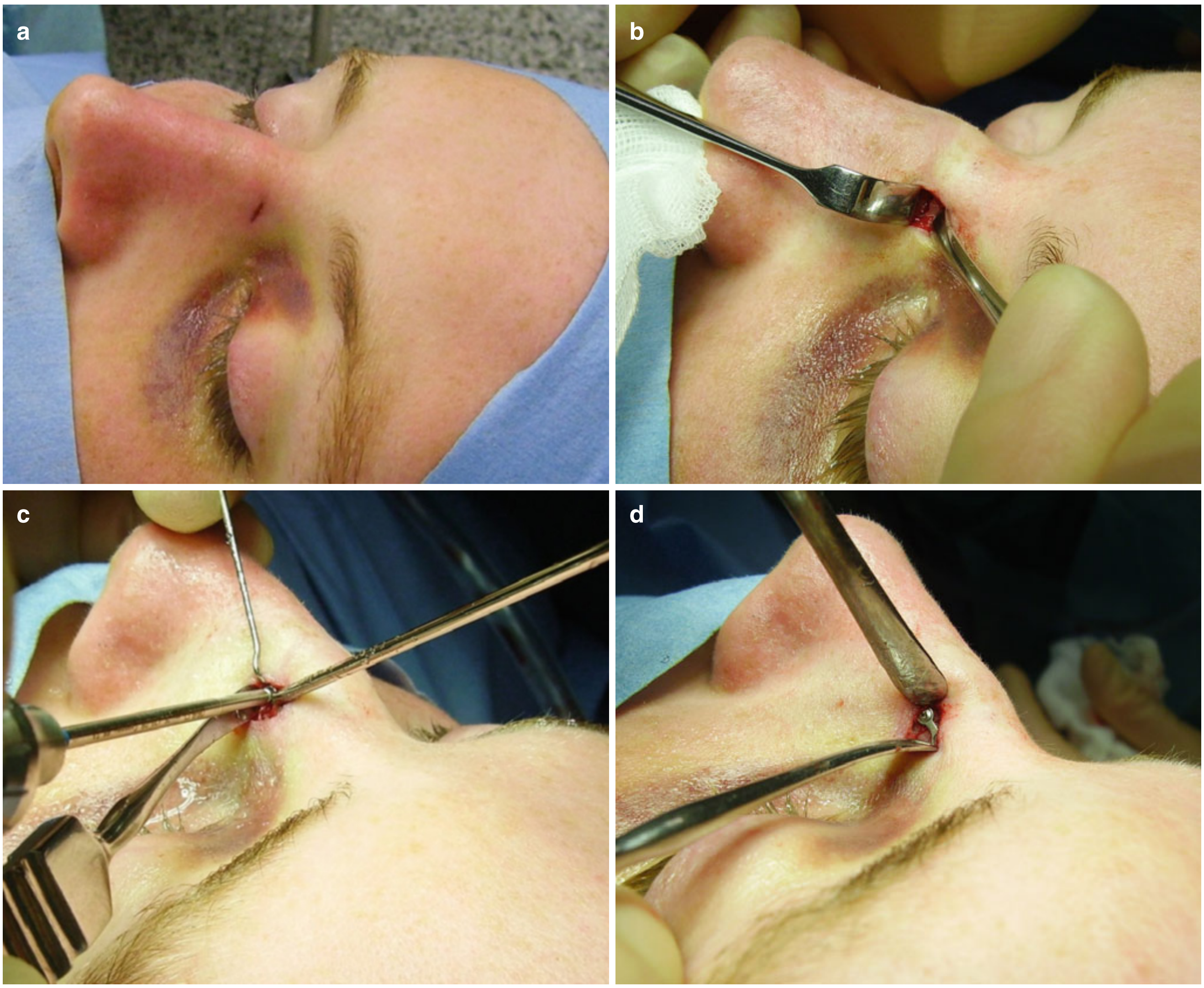

Fig. 10.49 ORIF of nasal bones through a 3-mm skin incision (**a–d**)

Case 2

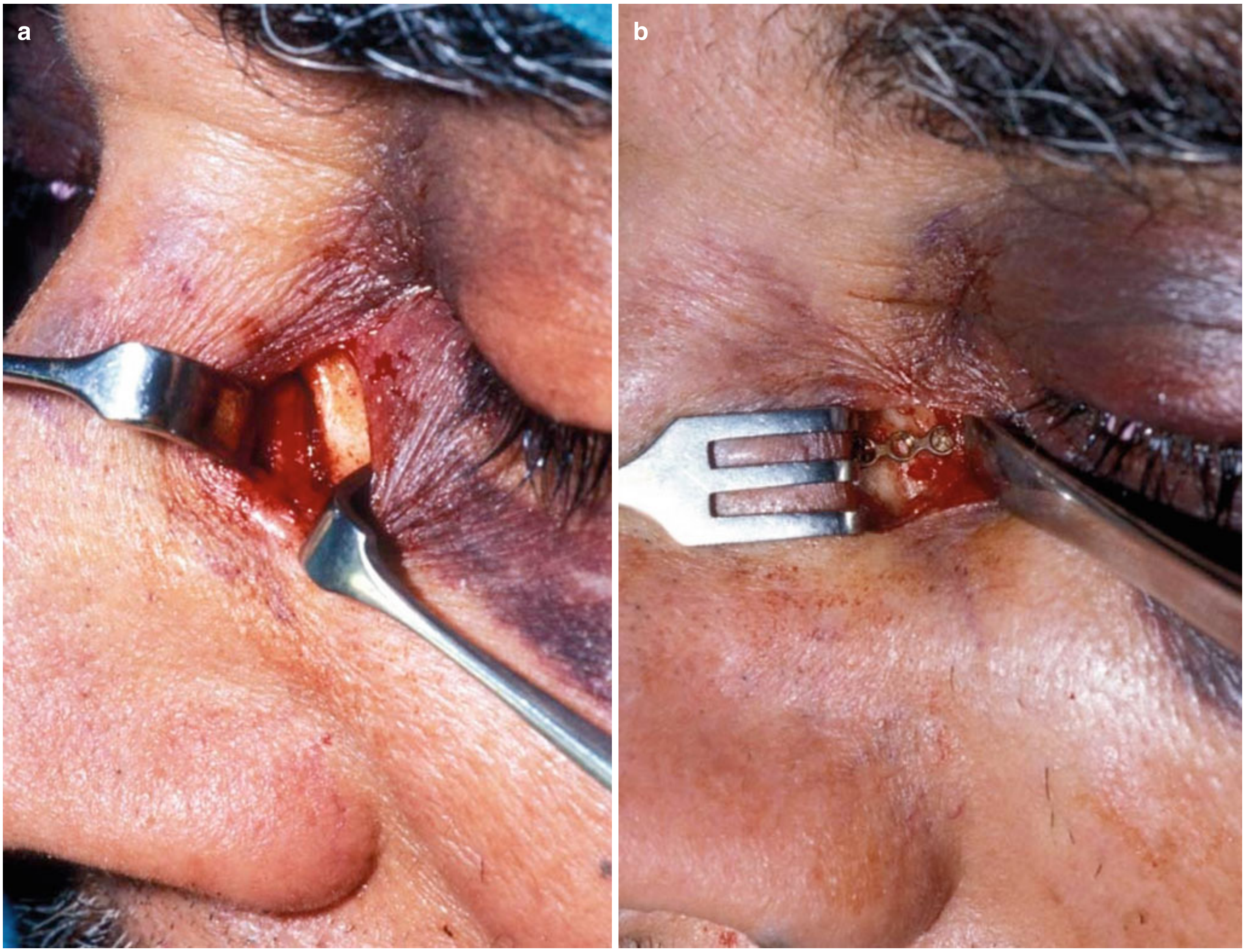

Fig. 10.50 Case selection is important (**a**, **b**)

Case 3

Fig. 10.51 This technique is best suited to simple fractures with overlying thick skin and nearby skin creases in which incisions can be placed

10.8 Nasomaxillary Fractures

Extension of the fractures beyond the nasal bones can result in more complex injuries. Nasoethmoid fractures are discussed elsewhere. Nasomaxillary fractures are fractures that extend into the midface (maxilla). These are perhaps more common than realised. Management depends on the amount of displacement and stability. Some fractures may be managed by simple manipulation and packing of the nose. Others are unstable and require fixation. Depending on the fracture configuration, these may be plated via an intraoral approach (along the piriform buttress) or transcutaneously/trasconjunctively if the fracture extends to involve the infraorbital rim. CT is advisable as some of these fractures may also involve the medial orbital floor. These can be deceptive injuries. They often look easy to reposition on the CT, but their complex three-dimensional geometry can be overlooked, especially along the internal nasal wall (*see* Figs. 10.52, 10.53, 10.54, 10.55 and 10.56).

Case 1

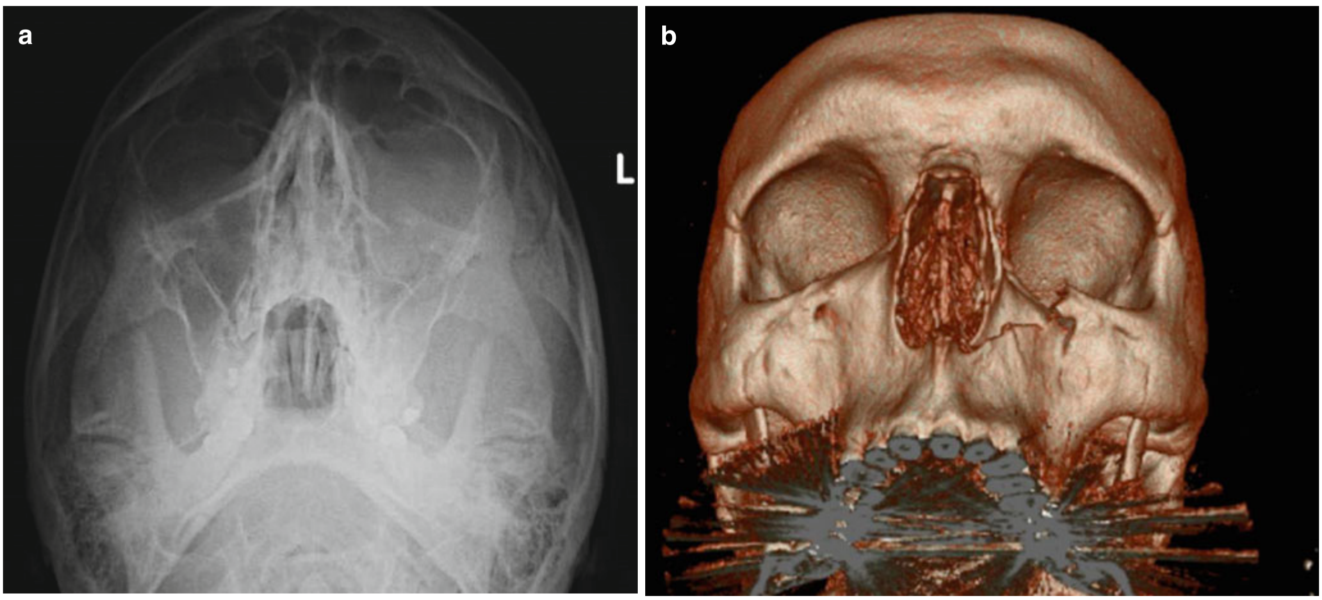

Fig. 10.52 Nasomaxillary fracture initially misdiagnosed as fractured nasal bones and a zygoma (**a**, **b**)

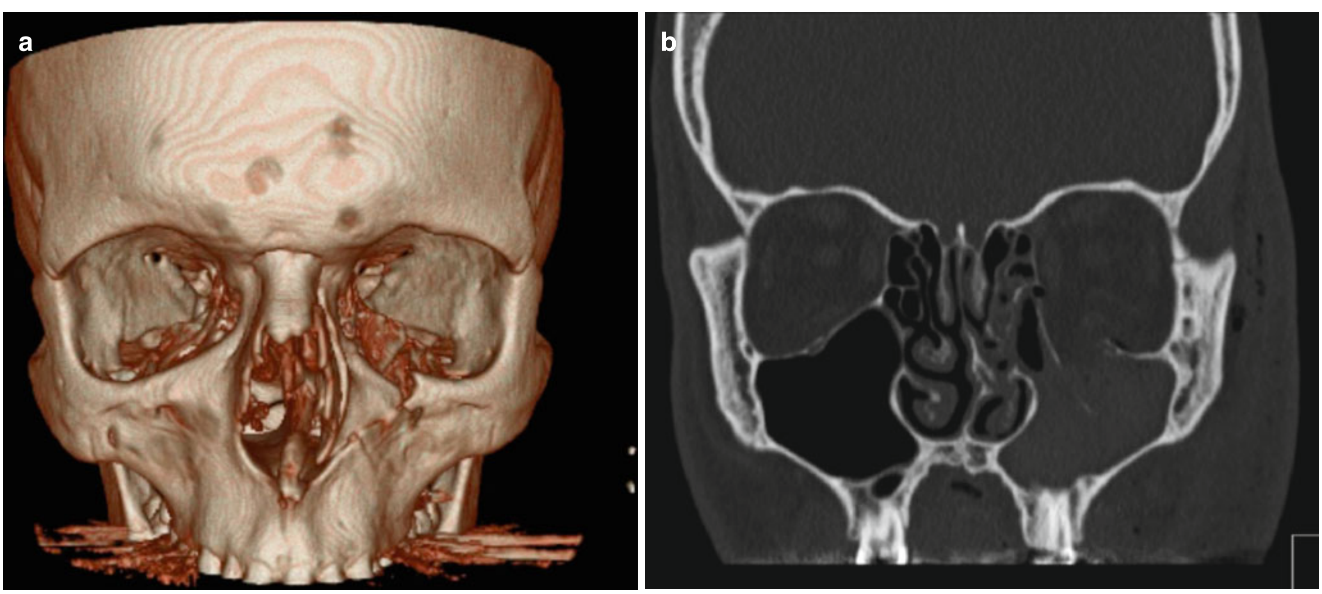

Fig. 10.53 What initially appears as a simple fracture is in fact more complex, involving the orbital floor and lacrimal apparatus (**a**, **b**)

Case 2

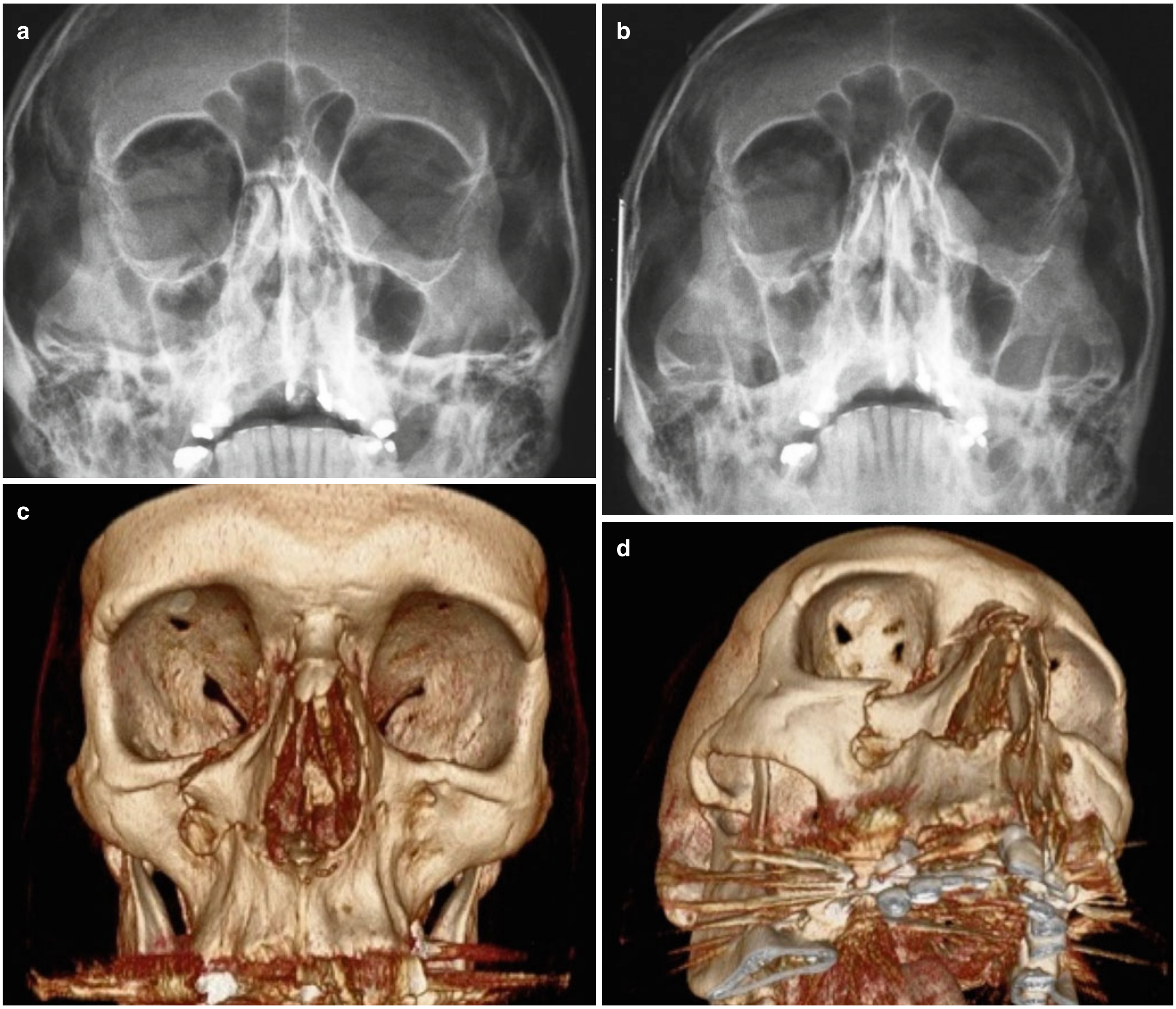

Fig. 10.54 Right nasomaxillary fracture with minimal orbital involvement. Note separation along nasal bones (**a**–**d**)

Fig. 10.55 Repair through 5-mm nasal incision (skin crease) and 1-cm infraorbital incision. (Alternative access includes transconjunctival and intraoral). Simple manipulation was not possible due to impaction and late presentation. Open reduction was therefore necessary

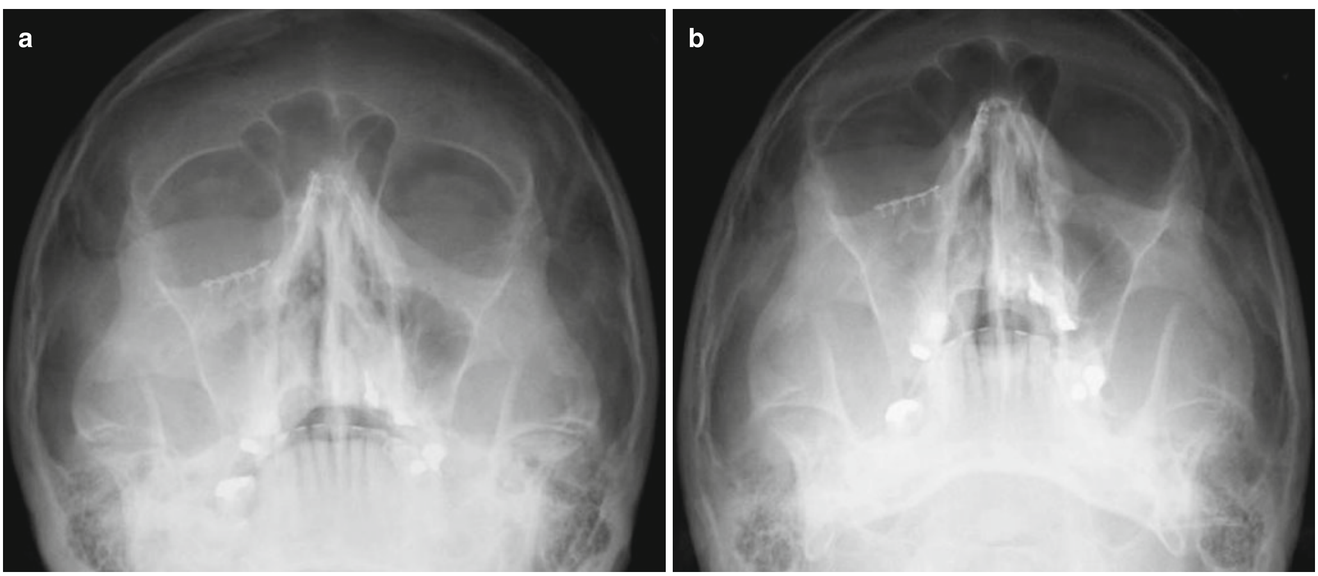

Fig. 10.56 Satisfactory postoperative reduction (**a**, **b**)

To the inexperienced practitioner, nasomaxillary fractures may be misinterpreted as coexisting fractures to the nose and zygoma. The nose is clinically deformed and the presence of a step at the infraorbital rim misleads the clinician to diagnose a fracture of the zygoma. The way to be sure is to see which side of the rim has dropped. If the medial (nasal) side of the rim is lower, it is a nasomaxillary fracture (a fractured zygoma cannot normally be displaced upwards).

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11 Nasoethmoid (Naso-Orbital-Ethmoid): NOE Fractures

Michael Perry and Simon Holmes

Nasoethmoid fractures are commonly regarded as fractures involving the nose, orbits and ethmoid sinuses. These usually occur following moderate to high-energy blunt trauma to the upper part of the central midface, or occasionally from an isolated impact to the bridge of the nose. However, nasoethmoid fractures also involve the drainage pathways of the frontal sinus and this aspect of the injury must also be carefully managed. "Naso-orbital-ethmoid-frontal" fractures (often abbreviated to NOE) are therefore among the most challenging injuries to treat. Fractures are often comminuted and complex and are easily overlooked or inadequately treated. Timely diagnosis combined with adequate exposure for internal fixation will minimise residual deformity, although it is often very difficult to restore all the elements of the injury with absolute precision. Involvement of the associated soft tissues is another critical element in these injuries. Both the canthal attachments and lacrimal apparatus make for considerable deformity and morbidity in inadequately treated or untreated cases. The nasal septum also needs careful attention and can be easily overlooked (see Fig. 11.1).

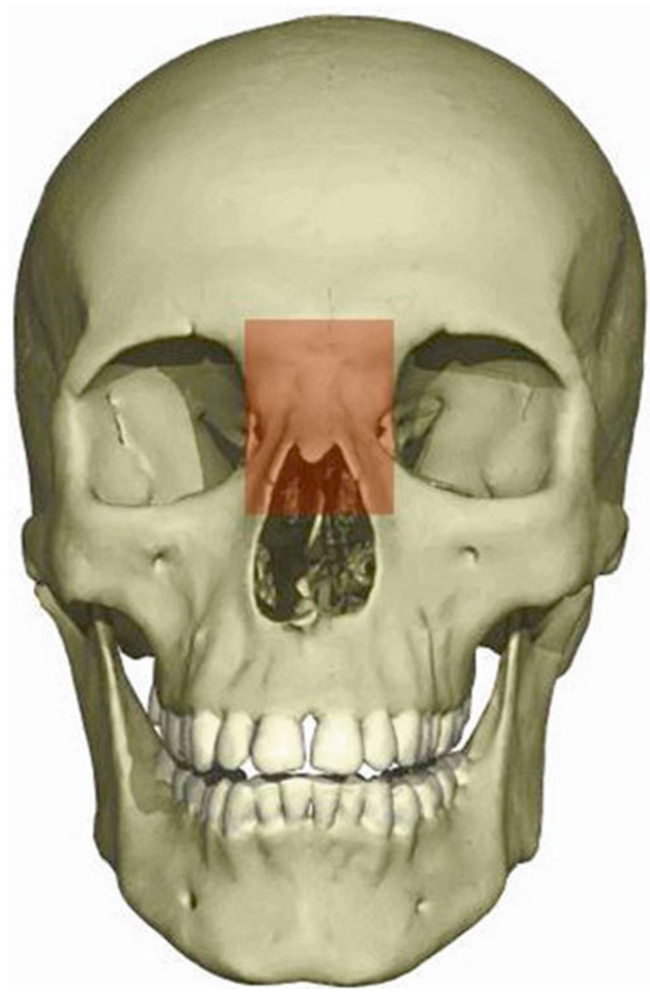

Fig. 11.1 The "naso-ethmoid-orbital-frontal" region (NOE) represents the confluence of a number of important anatomical regions. Injuries sustained here can appear deceptively minor (to the inexperienced they may be confused with nasal fractures). Management frequently involves craniofacial principles

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11.1 Applied Anatomy

The NOE complex is a delicate anatomical structure. This can be thought of as a central "block" of bone (composed of the ethmoid sinuses) situated between the orbits, surrounded by the bridge of the nose (anteriorly) and the frontal sinus and the anterior cranial fossa (ACF) superiorly. Anatomically the nasal, frontal, maxillary, ethmoid, lacrimal, and sphenoid bones make up the whole complex (see Figs. 11.2 and 11.3).

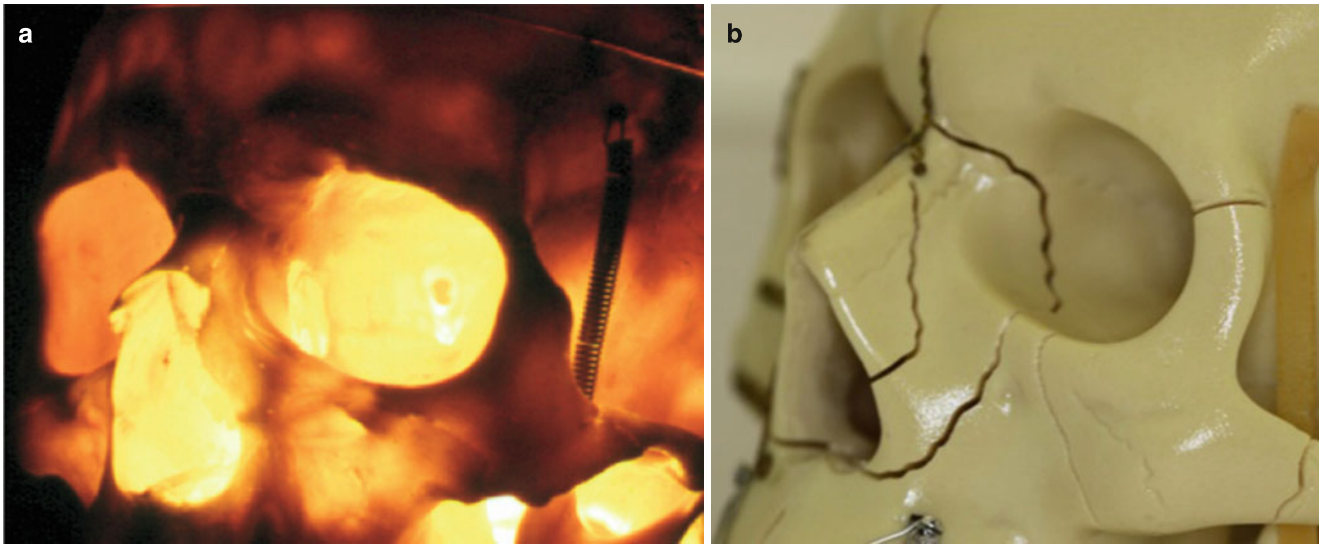

Fig. 11.2 On a dry skull the fragility of the bones of the face can be seen (**a**). The bones are especially thin within the ethmoid region, between the orbits. This can collapse in on itself following impacts to the upper midface. Depending on the degree of aeration of the ethmoid sinuses, surprisingly little force applied directly to the bridge of the nose can result in complex injuries

Fig. 11.3 Similarly, the anterior cranial fossa is "wafer"-thin. High-energy injuries in this region are frequently associated with skull base fractures and dural tears

Anteriorly, the frontal process of the maxilla and maxillary process of the frontal bone form one of the paired vertical "buttresses." Together with the nasal bones these form a relatively strong outer (or anterior) framework, to which the deeper more fragile structures are attached. The ethmoid bones and sinuses lay deep to the nasal bridge, occupying the space between the medial orbital walls and cribriform plate (which are themselves relatively thin). These form a labyrinth or "honey-comb" type structure (see Figs. 11.4 and 11.5).

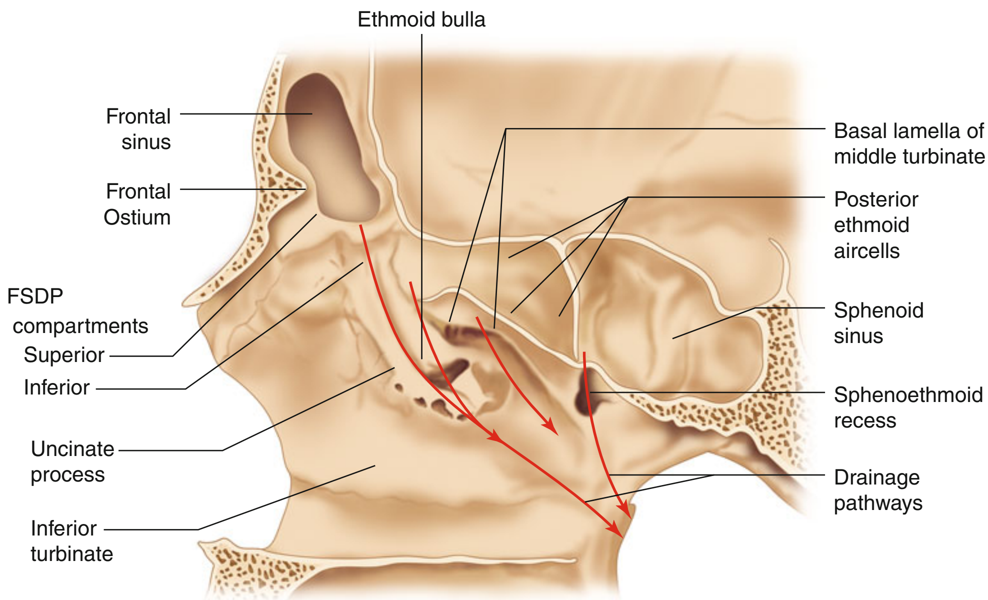

Fig. 11.4 The frontal sinus drains through the ethmoid region. When these structures collapse the "nasofrontal (frontonasal) ducts" are frequently damaged, preventing frontal sinus drainage. Although the frontal sinus may not be directly injured problems can develop months or years later as mucus collects, resulting in mucocele formation (see Fig. 11.5)

Fig. 11.5 Large mucocele formation following untreated NOE fracture several years previously. This has weakened the surrounding bones, resulting in further fracturing following a fall (**a**–**d**)

The deeper bones are particularly thin and can easily collapse under relatively low impact. As a result of this anatomical arrangement, NOE fractures often result in comminution of the ethmoid bones and medial orbital walls. These bones may be displaced laterally into the orbits, disrupting the orbital contents. It is this thinness of the deeper bones and the presence of comminution that makes repair of these fractures difficult. Furthermore, the nasofrontal (frontonasal) ducts (or frontal sinus drainage pathways) pass through this region and drainage can be impaired in severe injuries. The cribriform plate of the ethmoid, immediately above the ethmoid sinuses in the midline, can also be fractured. Dural tears and cerebrospinal fluid (CSF) leaks are therefore commonly associated with NOE fractures, although not all require dural repair (a controversial topic). The anterior and posterior ethmoid vessels pass along the medial orbital walls into the nose. If these are torn, significant epistaxis can occur. Although the orbital apex is relatively deep, NOE fractures can propagate nearby, making such injuries (and their repair) potentially vision-threatening (see Figs. 11.6 and 11.7).

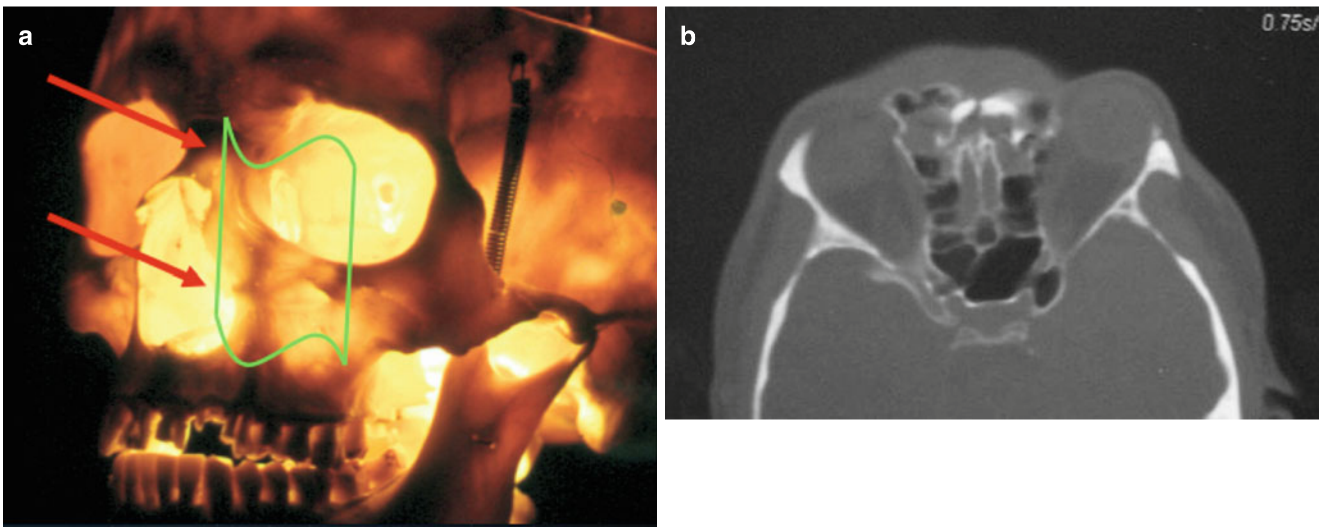

Fig. 11.6 Following impact to the bridge of nose/upper midface, the ethmoidal bones collapse in on themselves (**a**, **b**). The nasal septum also buckles or fractures. This is a good example of the "airbag" function of the sinuses—much of the kinetic energy is absorbed here rather than being transferred to the brain. Note the impaction of the bones and lateral displacement of the medial orbital walls. This is a complex injury which requires careful evaluation of the canthal attachments, lacrimal drainage apparatus, nasofrontal ducts and skull base. *Red arrows* indicate the direction of force

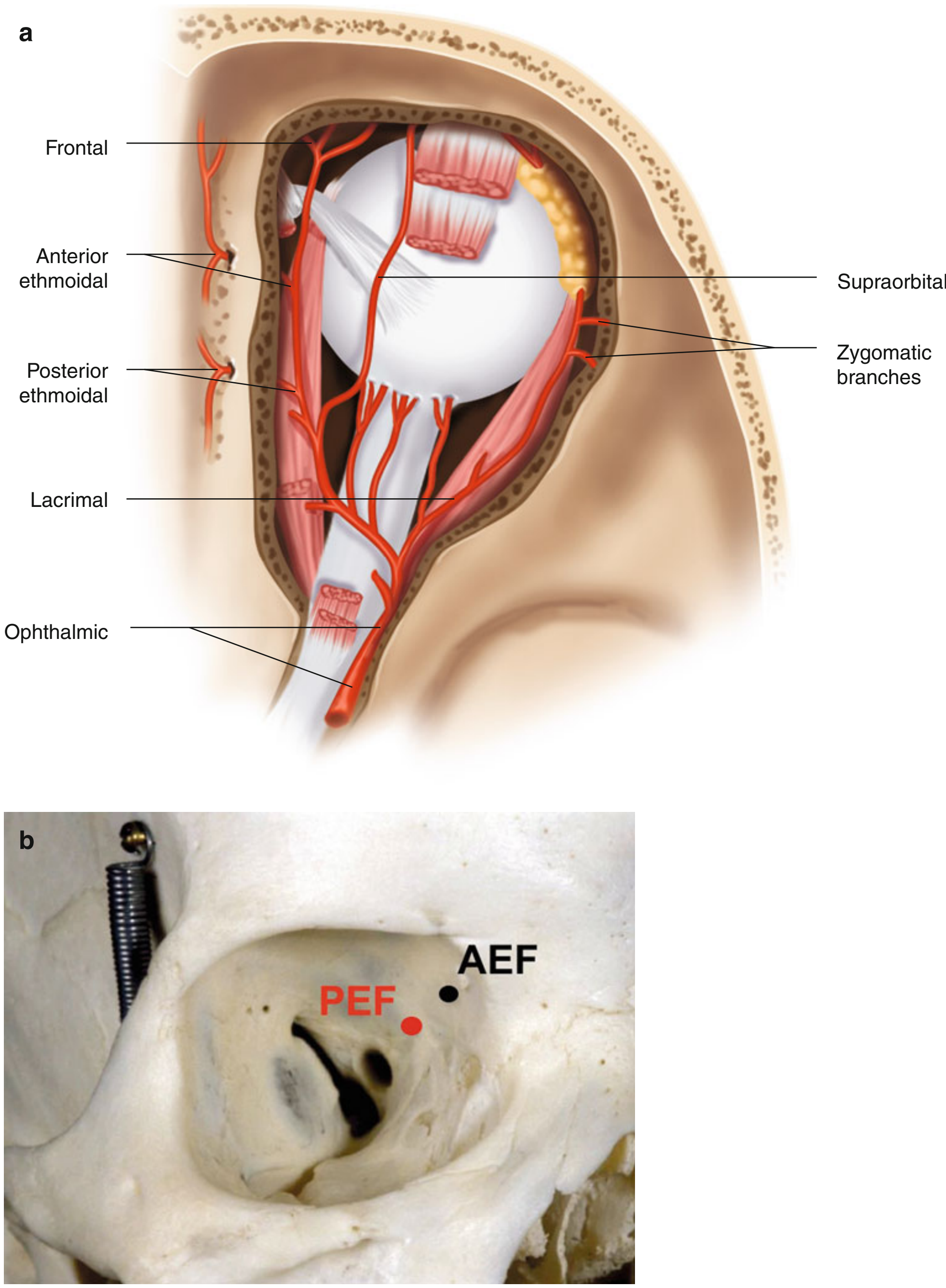

Fig. 11.7 The anterior ethmoidal foramen (AEF) and posterior ethmoid foramen (PEF) pass through the medial orbital wall (**a**, **b**). Significant epistaxis is a common problem with NOE fractures. If nasal packing is required, care must be taken in placement (disruption of the skull base, medial orbital walls and orbital apex)

11.1.1 The Medial Canthal Tendon (Medial Canthus)

The “medial canthus,” (or medial canthal tendon [MCT]) is a very important soft tissue component of the NOE region. This complex anatomical structure is variably described in the literature, but functionally is often considered as being composed of three “limbs” which insert into and around the lacrimal crest, along the anterior part of the medial orbital wall. Between these limbs lays the lacrimal sac within the lacrimal fossa. The MCT not only has great aesthetic importance in maintaining medial canthal shape and position, but due to the actions of the attached muscles it also generates a pumping action which assists in the passage of tears through the nasolacrimal system. Detachment of the MCT can result in malposition of the lower eyelid and an inability to drain tears (epiphora). The MCT also forms part of Lockwood’s suspensory ligament, which supports the globe. From a technical aspect the point of bony reattachment for a detached MCT is often deeper than would initially appear. This allows for any relapse and ensures that the eyelids remain in close contact with the globe during blinking.

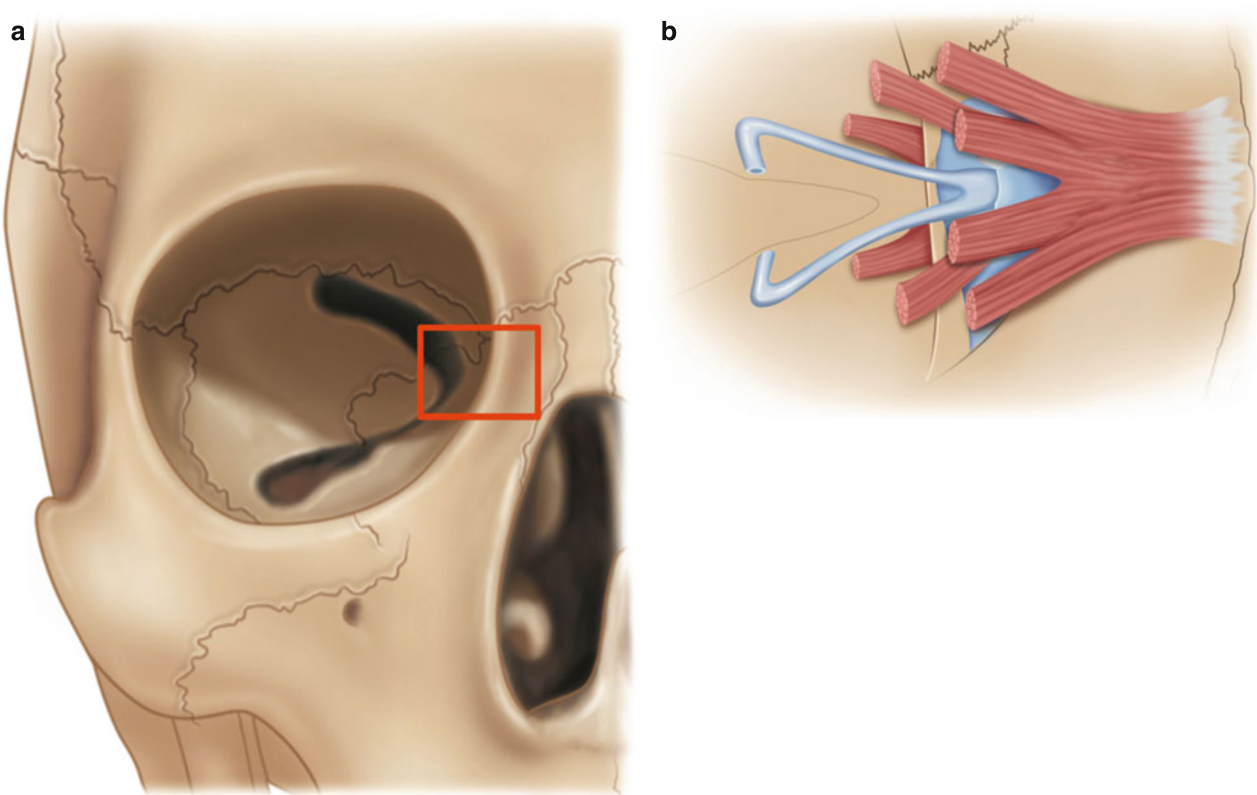

Fig. 11.8 The medial canthal tendon is functionally often considered as being composed of three “limbs,” which insert into and around the lacrimal sac within the lacrimal fossa (**a**, **b**). It not only has great aesthetic importance, but assists in the passage of tears through the nasolacrimal system. Detachment of the MCT can result in malposition of the lower eyelid and an inability to drain tears (epiphora)

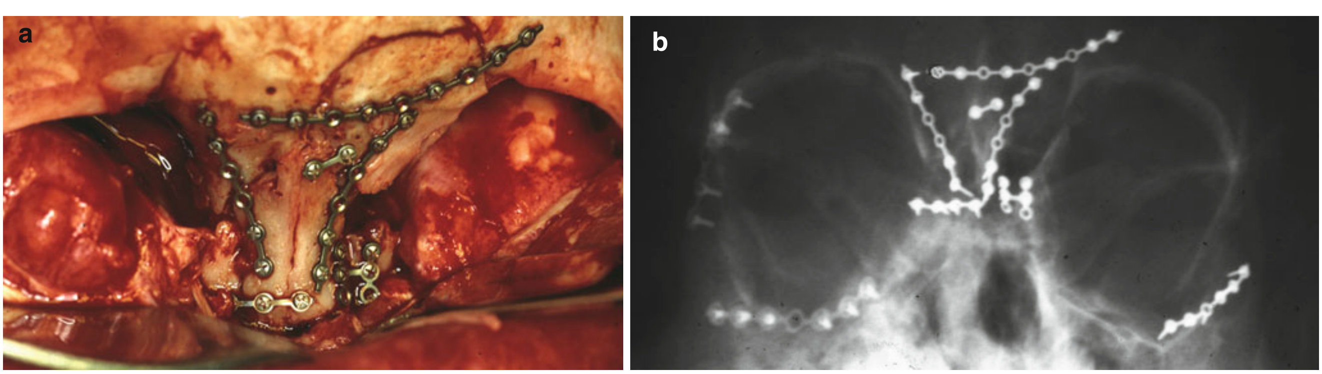

Fig. 11.9 Repair of NOE fracture (**a**, **b**). The canthal attachment is clearly visible. Note involvement of frontal sinus and medial orbital wall

11.2 Clinical Features

NOE fractures commonly occur following a direct blow to the upper part of the central midface, or bridge of the nose. This is often seen following assaults or "dashboard" injuries (where the upper face strikes the steering wheel or dashboard of a car, following a head-on collision). As a result, the ethmoid sinuses collapse in on themselves acting as a "crumple zone," absorbing much of the impact. This results in disruption to the medial orbital walls, canthal attachments, skull base and a "pushed-in" look to bridge of the nose, sometimes referred to as a "Miss Piggy nose." The frontal sinus is also variably affected. Relatively less force is required to cause NOE fractures compared to the rest of the midface and frontal bones. Depending on the amount of displacement and comminution of the bones, clinical appearances can vary. Sometimes these injuries are underappreciated and misdiagnosed as simple nasal fractures. Examination therefore needs to be both thorough and systematic (see Figs. 11.10, 11.11, 11.12, 11.13 and 11.14 and Table 11.1)

Table 11.1 Examination of NOE fractures

1. **Advanced Trauma Life Support**: consider the mechanism of injury and likelihood of NOE fractures
2. **Neurosurgical involvement**: dural tears/brain injury (usually mild contusion) Frontal sinus drainage
3. **Ocular injury/vision**: globe rupture, haemorrhage, etc.
4. **Orbital fractures**: medial wall, orbital apex, enophthalmos/proptosis
5. **Nasolacrimal injury**
6. **Canthal displacement** (**telecanthus**): the "bow-string" test assesses for this: the lateral canthus is pulled laterally; if the medial canthus is detached it will be pulled laterally
7. **Ongoing epistaxis** (may be overlooked in supine patients)
8. **Nasal/septal collapse**: loss of nasal projection with upturned tip ("Miss Piggy nose")

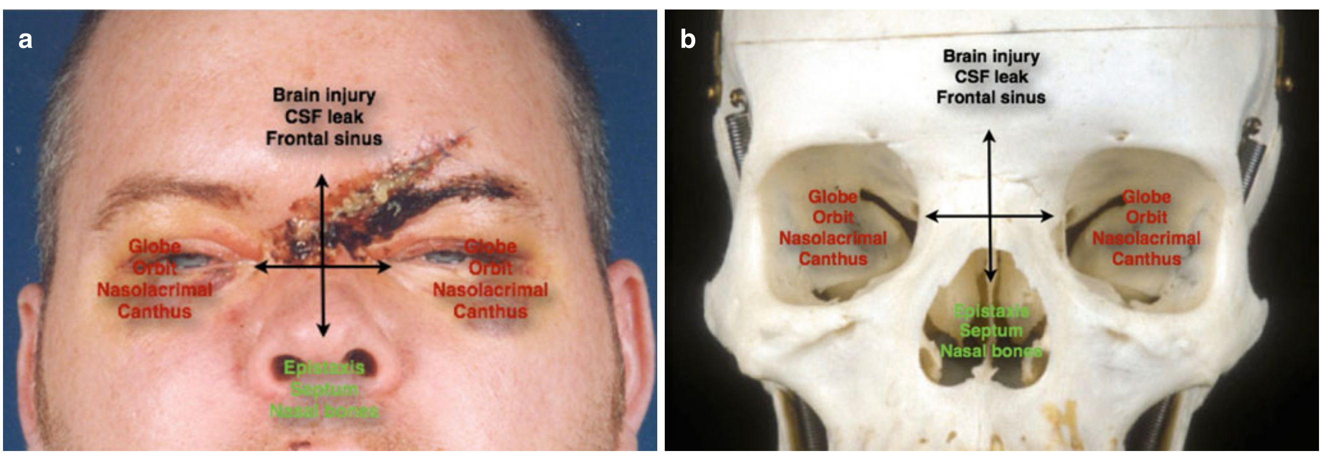

Fig. 11.10 Nasoethmoid fractures can be deceptive and present with an array of clinical signs and symptoms, depending on their severity (**a**, **b**). They are not always symmetrical and unilateral injuries may occur. These require careful evaluation, notably with CT imaging

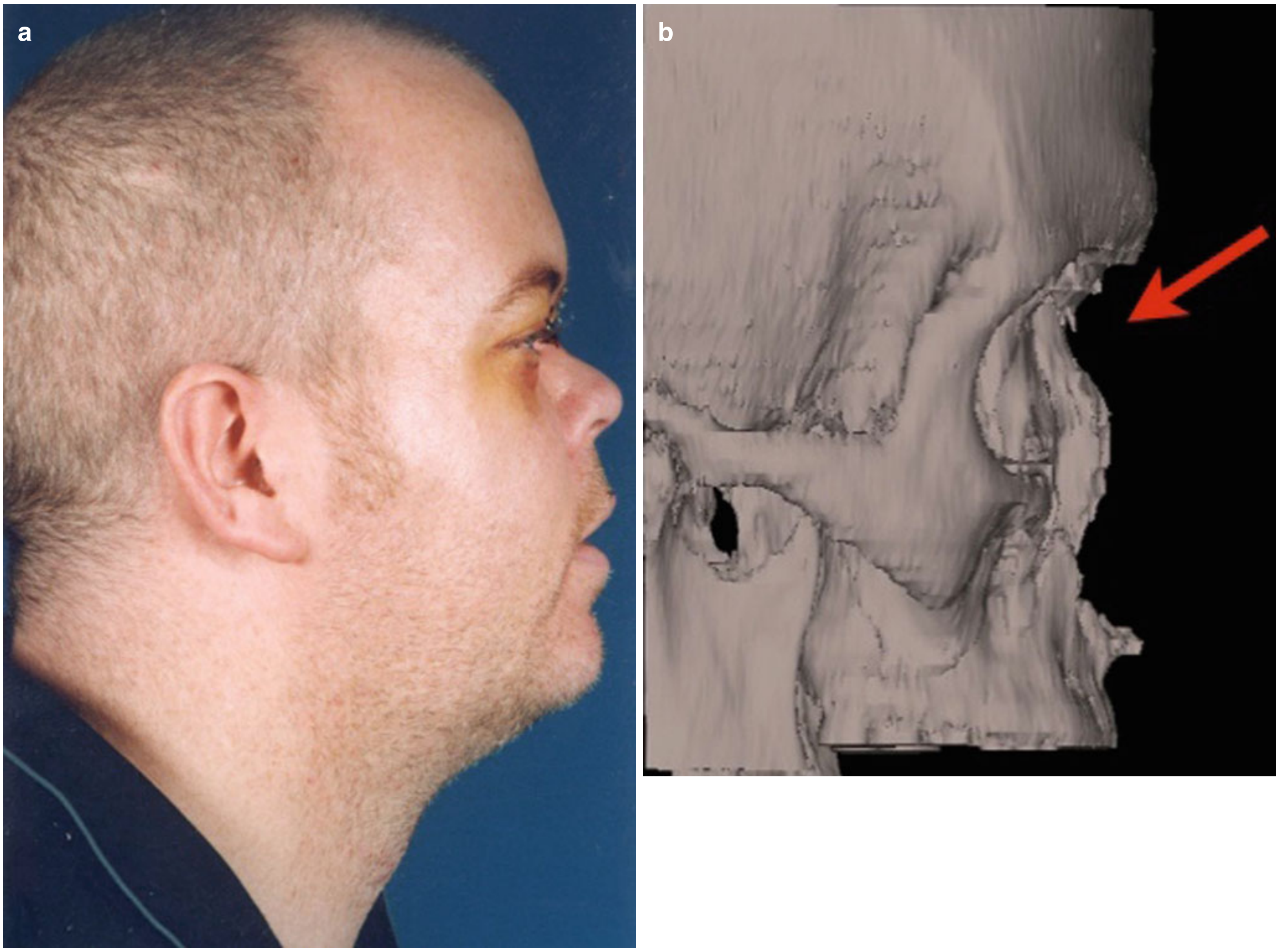

Fig. 11.11 Typical "Miss Piggy" appearance as the nasal bridge collapses into the ethmoid sinuses. The septum is also damaged, but less so lower down (**a**, **b**). This maintains a degree of nasal tip projection which then rotates up; hence the name

Fig. 11.12 Comparison of pre- (**a**, **c**) and postoperative (**b**, **d**) appearances illustrates the degree of impaction and exaggeration of nasofrontal angle

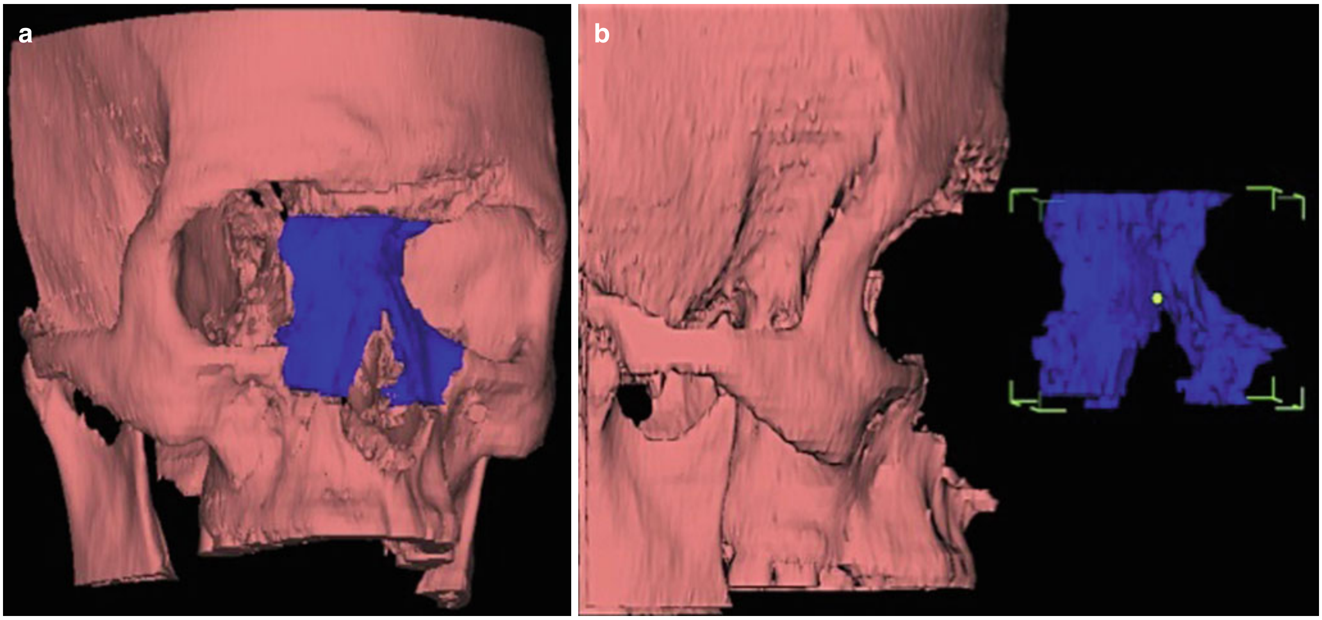

Fig. 11.13 Three-dimensional CT images (**a**, **b**). The fracture complex has been highlighted. In this case there is relatively little comminution

Fig. 11.14 Postoperative film

With higher energy impacts, bone fragments can collapse further and pass into adjacent cavities (nose, anterior cranial fossa, one or both orbits) (see Fig. 11.15). For this reason, severe injuries may result in CSF leaks, intracranial injury, or globe injuries. These take priority over the nasoethmoid fractures themselves. Any fluid leaking from the nose should raise suspicion of a CSF leak. A crude test for CSF may be performed by dripping a few drops of the nasal fluid onto filter paper and examining the stain. Blood tends to form a central pool, while CSF forms a second peripheral ring. This is called the "ring test." A more definitive test involves analysis of the fluid for beta-2-transferrin, although it is probably better to just assume a leak exists and manage accordingly.

A thorough eye examination is always essential, noting particularly the visual acuity, pupillary responses, and eye movements. In severe cases displacement of the medial orbital walls can result in proptosis, ocular dystopia and diplopia. If bone has impacted into the orbit consider the possibility of globe rupture. This can be present even if the eye appears to be noninjured (posterior scleral rupture) (see Fig. 11.16).

Fractures of the orbital floor may also occur resulting in dystopia and enophthalmos. Assessment of globe position and their movements is therefore necessary. Orthoptic assessment is discussed in Chap. 9. Although epiphora may be associated with NOE fractures, its presence during initial assessment is an unreliable indicator of injury. Any swelling in the area will clearly have a significant effect on lacrimal drainage. Lacrimal drainage may be assessed more accurately later when the swelling has resolved. This can be done by careful irrigation and probing of the puncta, or by performing the Jones dye test (placing a few drops of fluorescein in the lower fornix and waiting 5 min to see if it is detected within the nose using a cotton bud or light source). These tests are only reliable if there is no swelling and are therefore not undertaken in the early stages of assessment.

A key component in the assessment and repair of NOE injuries is the attachment of the medial canthal tendon (MCT). In minor injuries (i.e. "cracks" in the bones), the bony fragment to which the MCT is attached remains almost anatomical and may require no fixation. However, in more severe injuries the tendon, or the bone to which it is attached, may

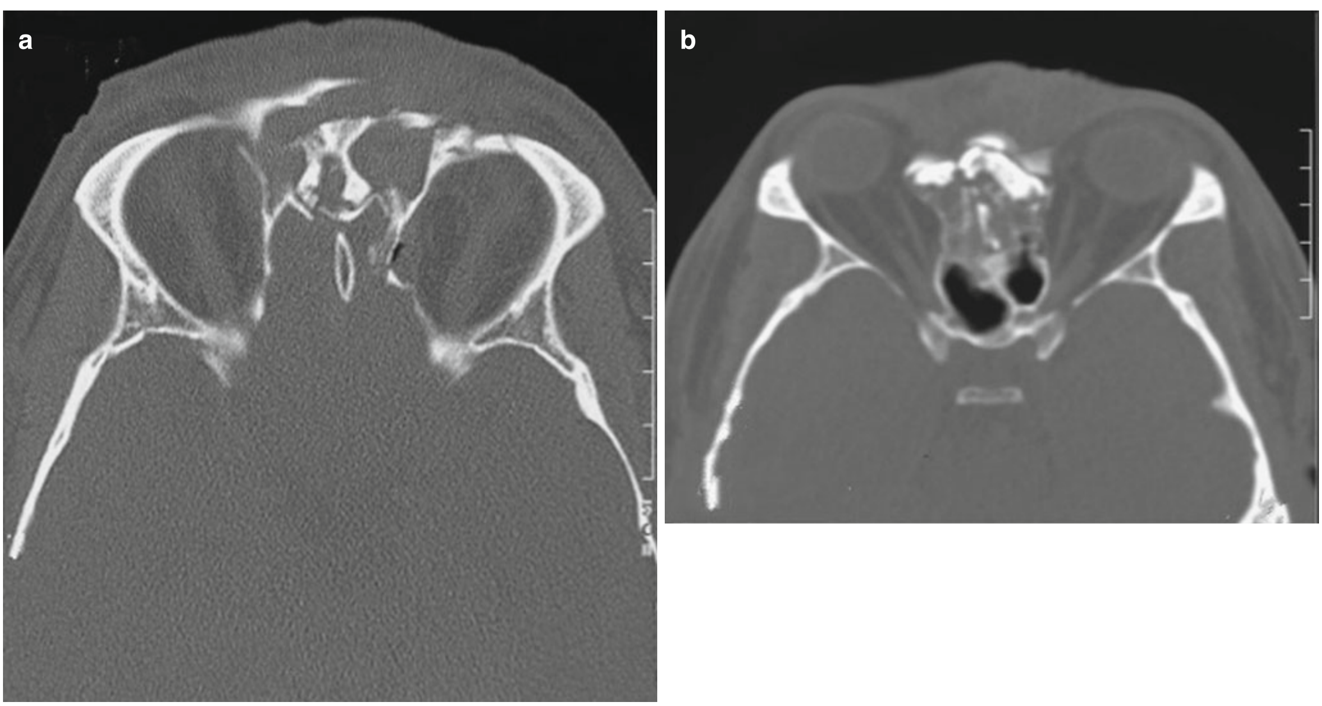

Fig. 11.15 Gross displacement of the nasal bridge and surrounding bones following a high-energy impact (**a**, **b**). The patient had bilateral proptosis, diplopia, telecanthus, epistaxis and CSF leakage

become completely detached from the surrounding bones. Tension from the eyelids and lateral canthus will then gradually cause lateral drifting of the medial canthus if it is not secured. In very severe cases displacement is immediately apparent as the nasal bridge acts like a wedge, pushing the canthi apart. Examination may therefore reveal a spectrum of deformity, from obvious displacement (telecanthus), to a more subtle rounding of the palpebral fissure medially, with lid laxity. Although computed tomography (CT) evaluation will be required, the "bow string" or "eyelid traction" test is a useful clinical test. The lower lid is pulled laterally while palpating the medial attachment. Although movement may indicate instability of the canthal attachment, lack of movement is no guarantee that the canthus is secure—it may be trapped by impacted bones, only to become loose following their reduction. CT is therefore still required in order to define the type and extent of injury.

When assessing injuries to the NOE region, a number of useful measurements can aid in diagnosis. The intercanthal distance (ICD) should be measured and compared to the palpebral width of both eyes. If the ICD is significantly greater, traumatic telecanthus from a NOE fracture should be presumed. If swelling makes localization of the medial canthus difficult, an alternative is to measure the interpupillary distance (IPD). This should be approximately double the ICD. Therefore if the intercanthal distance is more than half the interpupillary distance, traumatic telecanthus must again be considered. A further aid is to use the "rule of fifths," as shown (see Fig. 11.17). However, these are all just guides. Anatomical and ethnic variations are well known. Preinjury pictures are therefore particularly helpful.

Assessment of the nasal septum is also important. Any collapse of the nose will result in buckling or fracture of this structure. This needs careful attention during the repair of NOE fractures. Although the nasal bones can be plated at the nasofrontal suture, there will still be a tendency for them to "sag" if they are not supported adequately from below (by the septum).

Fig. 11.16 Lateral displacement of the canthal region with impaction into the globe may result in scleral rupture

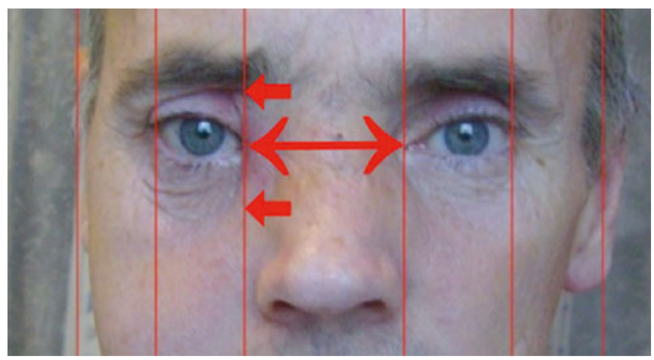

Fig. 11.17 The "rule of fifths." The palpebral width, ICD, and distance from lateral canthus to side of the face should all be approximately equal. In this case, the ICD is considerably increased with a corresponding reduction in the palpebral width, mostly on the right. Together with broadening of the nasal bridge, this is clearly an NOE fracture. The *double arrow* is the intercanthal distance. The *single arrow* is a line through the medial canthus indicating lateral displacement

11.3 Classification

The severity of injury to this region can vary considerably, and the extent of comminution, displacement and skull base involvement cannot be determined precisely on plain films. CT is therefore essential. Usually there will be significant comminution and associated soft tissue injuries. Based on CT findings, NOE fractures can be classified into one of three types (see Table 11.2 and Fig. 11.18).

Table 11.2 Markowitz classification of NOE fractures

Type I: Central Fragment intact
The simplest fracture. There is no comminution. The MCT is fully attached to the bone. In these fractures the bony fragment may be relatively easily reduced and fixed if necessary. Fractures may be unilateral or bilateral, displaced or undisplaced
Type II: Comminution of major fragments, ligaments attached
These are comminuted fractures which extend beyond the insertion of the MCT. However, the tendon maintains its attachment to a segment of bone which may be possible to repair
Type III: As with type II, but ligaments not attached
These fractures are often bilateral with comminution extending beyond the insertion of the MCT. The MCT may not be totally avulsed, but the bony fragment to which it is attached is usually too small to be of use in repair
Occasionally the MCT is torn or avulsed completely from its intact point of insertion

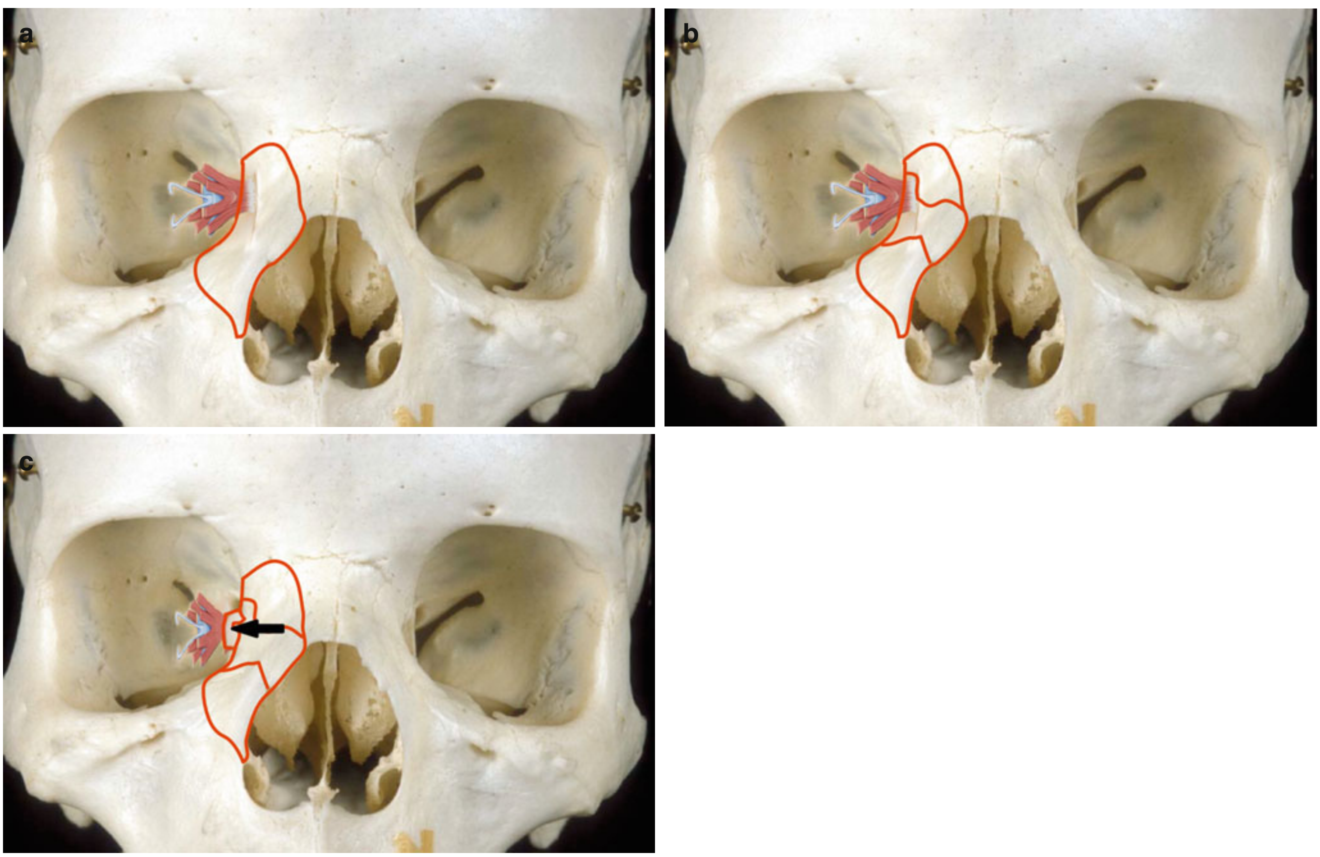

Fig. 11.18 (**a**) Markowitz 1. A 'monobloc fracture. (**b**) Markowitz 2. Comminution of the central fragment, but the canthal tendon remains attached to bone (**c**) Markowitz 3. Comminution of the central fragment with detachment of the canthal tendon

11.4 Management of NOE Fractures

Treatment planning and surgical repair of NOE fractures frequently requires craniofacial principles. The frontal sinus needs to be managed appropriately and these elements of repair are discussed elsewhere. The following discussion focuses on the subcranial component of management.

11.4.1 Initial Management

Nasoethmoid injuries may occasionally require urgent intervention to control profuse epistaxis. Although immediate fracture reduction often controls haemorrhage in orthopaedics and midface trauma, with NOE fractures this should not be forcibly attempted before a CT has been done. This is due to the risks of associated anterior cranial fossa (ACF) and orbital apex fractures which may be unfavourably manipulated in the process. Furthermore, once reduced, fractures need to be maintained in the reduced position and this would not be possible with a collapsed, mobile nasal bridge. In many cases manual disimpaction is not possible anyway. Nevertheless profuse epistaxis cannot be ignored and must be quickly controlled. This may require cautious light packing, or the use of nasal balloons, despite the small risks of ACF fractures. However, this should be done by someone familiar with the technique. Never force a pack in. The nasal anatomy will be severely disrupted and forceful packing can displace bones unfavourably. If this proves to be too painful for the patient and significant bleeding is still ongoing, urgent intubation and anaesthesia may be necessary.

Immediate intervention may therefore be indicated to initially stabilise a patient. At this early stage, definitive treatment can be safely deferred to allow resuscitation and further evaluation. Any large, open wounds should be meticulously cleaned as soon as possible. Wounds that may be used to access the fractures later may be temporarily closed and dressed. Antibiotics are usually given due to the risks of sinusitis and toxic shock syndrome (a risk of prolonged nasal packing) (see Figs. 11.19 and 11.20).

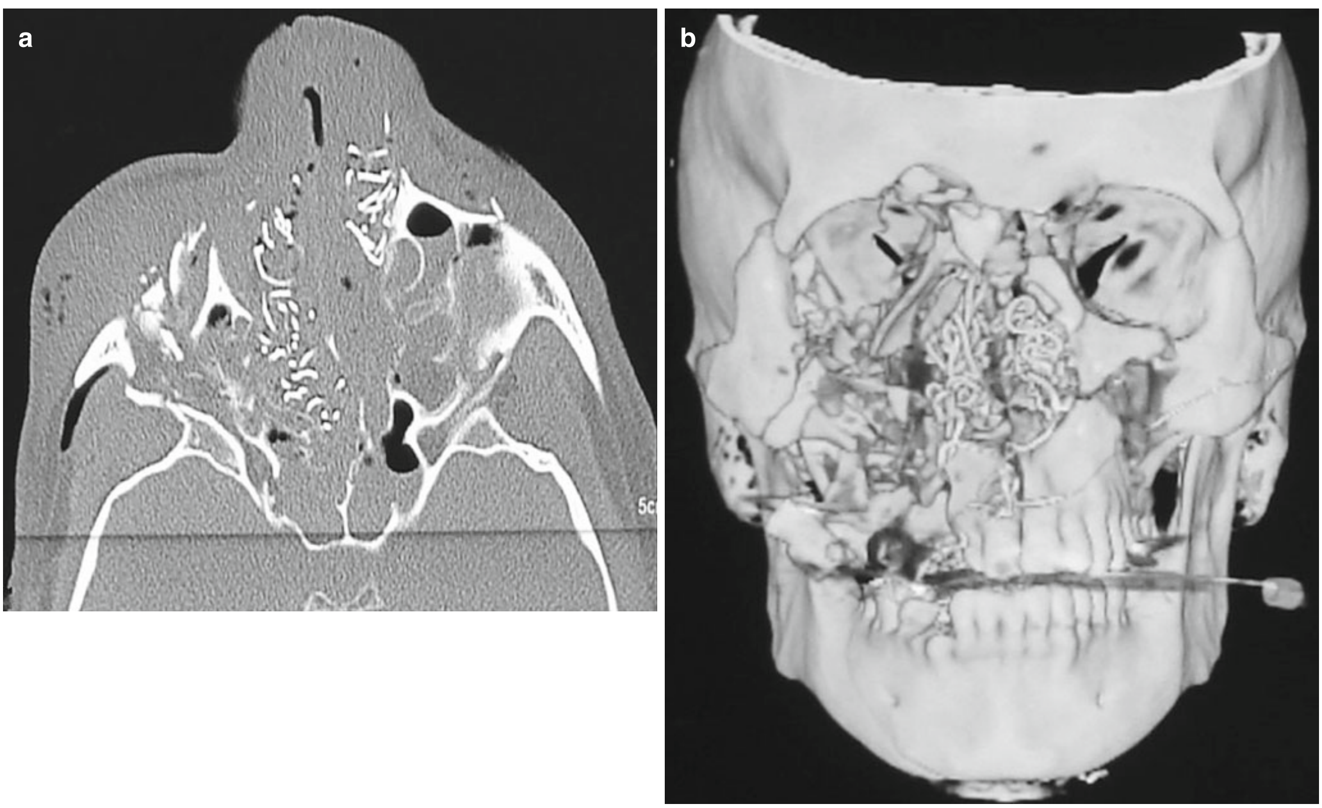

Fig. 11.19 Nasal packing can displace mobile fractures (**a**, **b**). Never pack aggressively. In this case of severe comminution following a protracted assault with a baseball bat and torrential midfacial bleeding, tamponade may be impossible without displacement of fracture elements - the pack has encroached into the right orbit and antrum

Fig. 11.20 Wounds should be temporarily cleaned and closed as soon as possible. Some of these may provide useful access to the underlying fractures during repair

11.4.2 Closed vs Open Treatment

Nonoperative management may be appropriate in selected cases where the fractures are minimally displaced, or when the general condition of the patient precludes complex, lengthy surgery. Occasionally, simple closed reduction of the nasal bones and the septum under a brief general anaesthetic may be all that is required. Case selection is important since the canthus is not fixed. Any closed reduction relies on intact periosteum to maintain the bones (and canthal attachment) in the correct position. Generally speaking, NOE fractures that are either significantly displaced or mobile require open reduction and internal fixation. Usually the best cosmetic result is obtained when repair is carried out at an early stage. The sooner the better (swelling and other injuries permitting) (see Table 11.3).

Access and repair of NOE injuries depends on the type of fractures present, their displacement and involvement of adjacent structures (notably ACF, frontal sinus and orbits). Not every fracture in these injuries can be repaired, but this is not essential. The complex "honey-comb" structure of the ethmoid sinus does not require repair, although it must be able to maintain free drainage. These bones and (more importantly), the medial orbital walls, are too thin to support any screws. Depending on the size of the orbital defects, bone grafting or alloplastic implants may be required. However, not every medial orbital wall fracture needs repair. With minimally displaced fractures, realignment of nose and the orbital rim may realign the medial wall sufficiently, if the periosteum has not been torn. Small defects may be accepted. The wall will still need to be visualised to verify this. CT imaging of this area is therefore essential to plan treatment and ensure adequate exposure.

Table 11.3 NOE fracture repair

Consider the following in your planning:
"Rigid" fixation of the orbital rims, nasal and nasomaxillary bones (buttresses)
Reattachment of medial canthus (see text)
"Overcorrection" of the canthus. This has a high risk of relapse
Bone grafting of the nose/orbital walls as needed
Titanium reconstruction of the orbital walls as needed
Attention to redraping of the soft tissues
Realignment of the nasal septum

It is the canthus that needs particular attention. The NOE region is a key site for aesthetics. If the canthus drifts by more than a millimeter or so, it will be noticeable. Anatomically precise repair of this site is therefore essential—but it is often technically difficult. This is why these fractures often have residual deformity if they are critically evaluated. A number of key considerations are now well known when planning repair (see Table 11.3).

The nasal septum is also a key consideration in the management of NOE fractures and can be easily overlooked. The septum is crucial in maintaining nasal projection and is discussed in the chapter on nasal injuries. Realistically, if the nasal bones and septum are extensively comminuted, it is unlikely that preinjury appearances will be fully restored. A combination of onlay bone grafting and prolonged septal splintage may be required to minimise the secondary deformity—but deformity is likely. Management of the lacrimal apparatus is discussed later.

Despite being a relatively localised injury, the management of NOE fractures therefore depends on a number of key elements, which will guide the extent of repair and access required. These are summarised in Table 11.4 (see Figs. 11.21–11.24).

Table 11.4 Treatment planning for the NOE case

Neurosurgical involvement: dural tears?
Ophthalmic involvement: globe injury/lacrimal stenting or repair?
Access: local incisions or wide exposure
Addressing the orbits: anatomical repair, especially the medial walls
Addressing the nose: re-establishing nasal projection and nasal airway patency
Addressing telecanthus: anatomical canthal repair is essential
Addressing the frontal sinus: has drainage been restored? If not, then how?
Bone grafting: is this required?
Soft tissues: wounds and redraping
Indications for repair
Cerebrospinal fluid leakage (controversial)
Telecanthus
Orbital dystopia/restricted eye movement
Nasolacrimal duct obstruction
Nasal deformity or obstruction from septal deviation
Obstruction to frontal sinus drainage

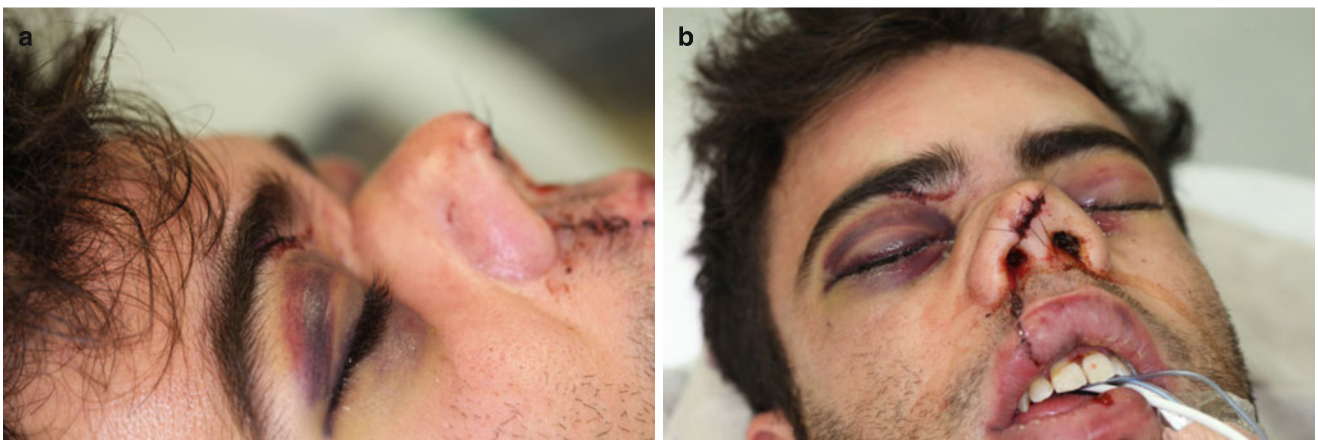

Fig. 11.21 Typical clinical appearances of a NOE fracture (**a**, **b**). Note the "Miss Piggy" nose with upturned tip and depressed nasal bridge. Also tram lines are evident on the left cheek indicating CSF leakage

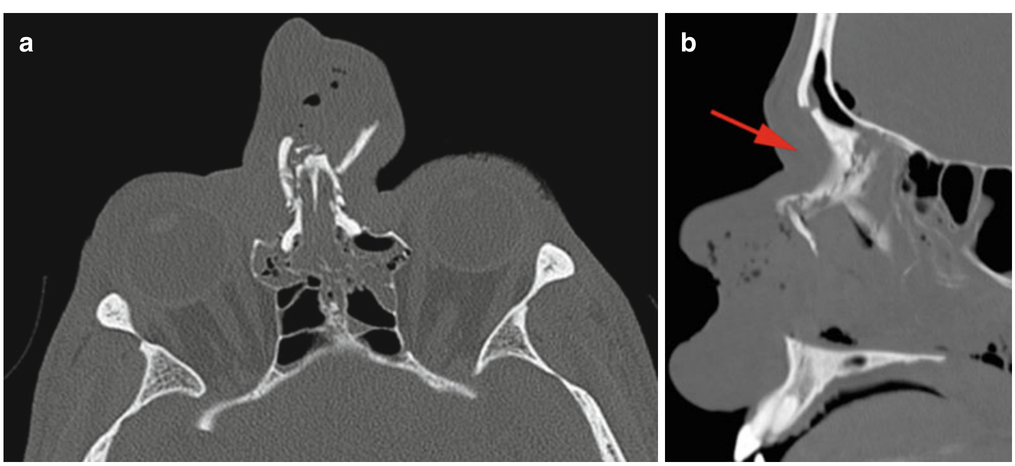

Fig. 11.22 CT imaging is essential to define the extent of this injury (**a**, **b**). There is clearly collapse of the nose into the ethmoid sinuses with outward displacement of the canthal regions and medial orbital wall. There is also intracranial air confirming the clinical suspicion of a dural tear. Neurosurgical and ophthalmic opinions should be sought. *Red arrow* indicates the direction of force

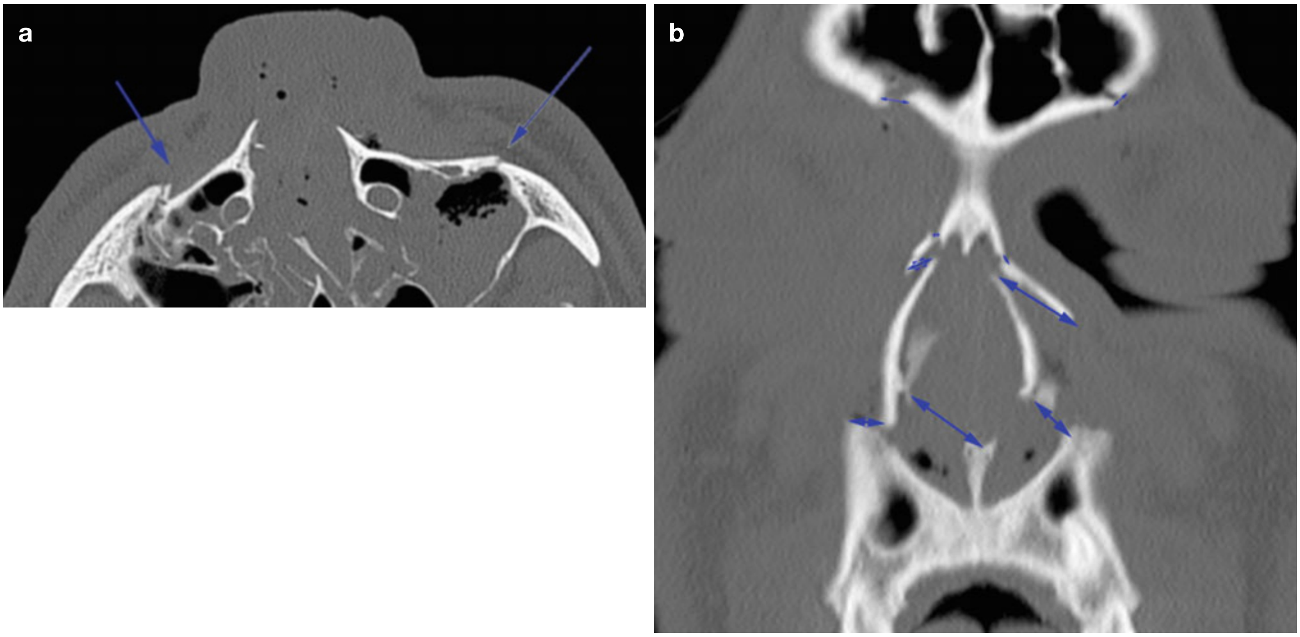

Fig. 11.23 Lower down the fractures extend into the maxillae (**a**). Note the gross displacement of the nasal septum on the axial view (**b**). *Blue arrows* demonstrate the fracture articulations

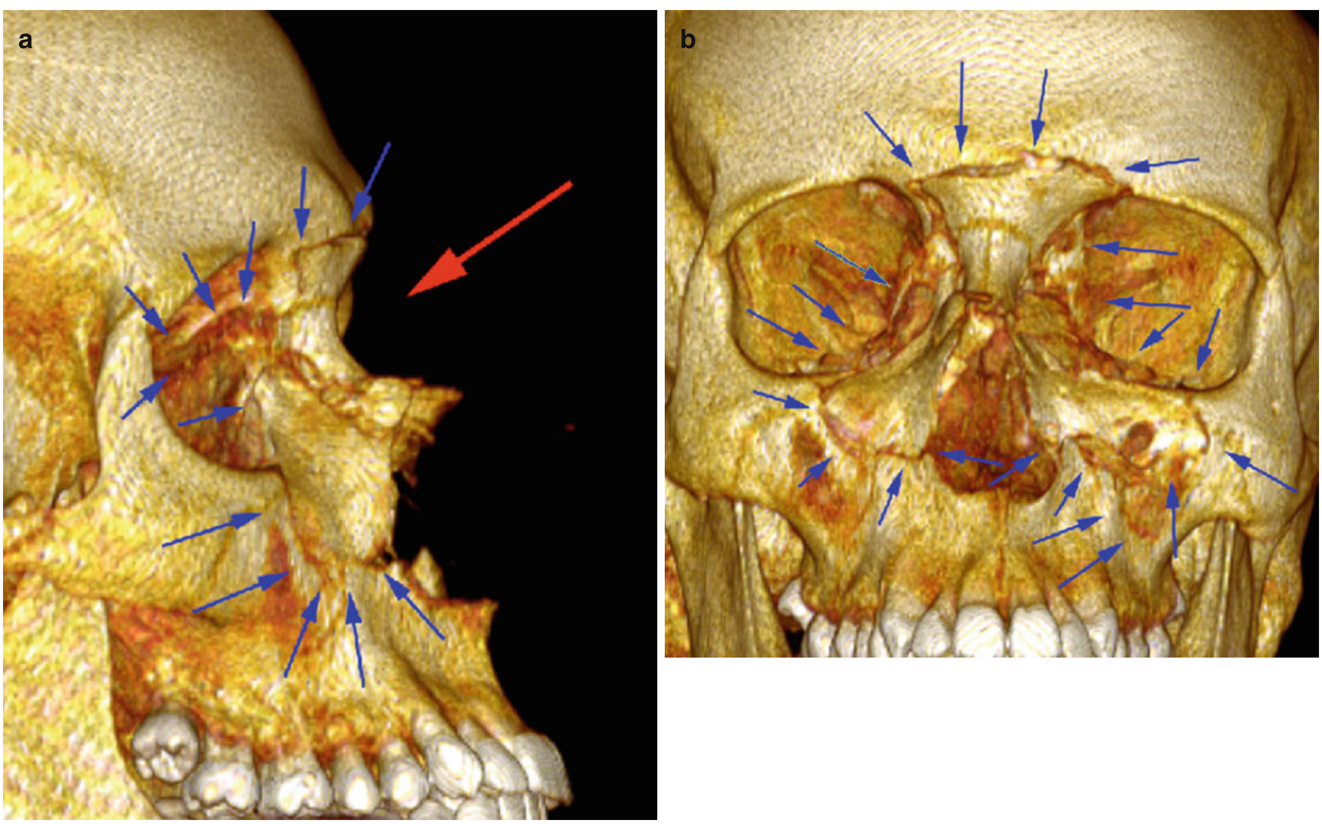

Fig. 11.24 Three-dimensional reformatting greatly assists in visualising the entire fracture configuration and in planning repair (**a**, **b**). *Red arrow* indicates direction of force. *Blue arrows* indicate the fracture margins

11.5 Canthal Repair

Precise canthal repositioning in NOE fractures is essential both during primary repair and secondary reconstruction in delayed cases. Unlike other regions of the face (where a 1- or 2-mm error may not be too noticeable), malposition of the medial canthus is much more obvious. Over the years many different techniques have been devised, all providing varying degrees of stability. Originally lead plates were used. These were hand-shaped to fit the contours of the canthus and placed externally to support the fractures, in the hope of achieving bony union in the correct position. Not surprisingly, poor results were common.

Today, direct canthal fixation provides a more accurate and stable repair. But despite this advance, relapse with drifting of the canthus can still occur. This is seen particularly when repair is delayed, or in cases of late posttraumatic reconstruction. The degree of comminution of the canthal region also has a significant impact on stability and relapse. Large bony fragments (Markowitz type 1 fractures) can support stronger plates and more rigid fixation, facilitating a stable anatomical repair. However, small comminuted fragments or detachment of the canthus altogether (Markowitz type 3) makes precise repositioning of the tendon far more difficult. Rigid fixation of small fragments is generally not possible. Today, a number of direct fixation techniques are now possible, some of which are described here. Which is used depends on a number of factors (surgeon's preference, available access, fracture configuration and extent of canthal injury).

11.5.1 Direct Access via Overlying Lacerations

Overlying lacerations often provide excellent access to the underlying fractures, but at the same time they can sometimes hinder precise determination of the medial canthal tendon insertion. By their very nature, these injuries will usually follow high-energy blunt trauma, where the soft tissues are split open and the bones are comminuted. Other mechanisms may include being struck with a sharp instrument (cutting/grinding equipment, or machete). Although the lacerations may provide good access, the added soft tissue component of this injury will predispose patients to residual soft tissue deformity. Access may also be limited to deeper structures, which may be required if problems arise during repair (notably CSF leakage). Case selection is therefore very important if no additional access is intended.

If the canthus is attached to a large fragment of bone (Markowitz type 1), this can be repositioned relatively easily. However, if the canthus has been completely detached from the underlying bone (Markowitz type 3), precise repositioning and secure fixation will be difficult. Using the opposite canthus as a guide to its position is very helpful, unless of course the injury is bilateral. In the example shown, the canthal tendon was relatively easily identified but it was completely detached from bone. Following repair of the underlying fractures (right zygoma and medial orbital wall), reattachment was achieved by first securing a 1.5-mm titanium plate along the medial orbital wall, placing one of its holes over the predetermined site of canthal reattachment. The canthus was then secured to this hole using a wire ligature. Choice of ligature is a matter of personal preference, although a nonresorbable material is probably the best choice. The overlying laceration was closed in layers.

Case 1

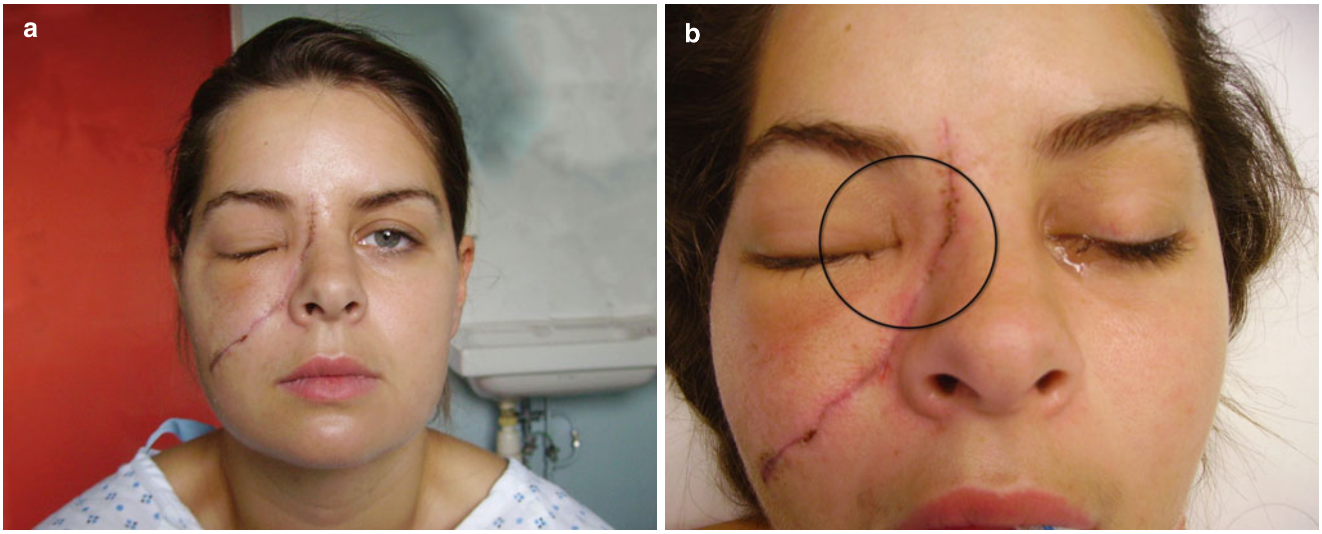

Fig. 11.25 This patient was kicked in the face by a horse (**a**, **b**). The main force of the kick was absorbed by the right cheek resulting in a ruptured globe and extensive fractures to the right zygomaticomaxillary complex (ZMC). There was also extensive degloving of the soft tissues around the medial canthal region with avulsion of the canthal attachment and nasolacrimal duct. The canthus had drifted laterally (*black circle*) as shown. The globe was enucleated and the laceration temporarily repaired prior to transfer. Note the increase transverse facial width

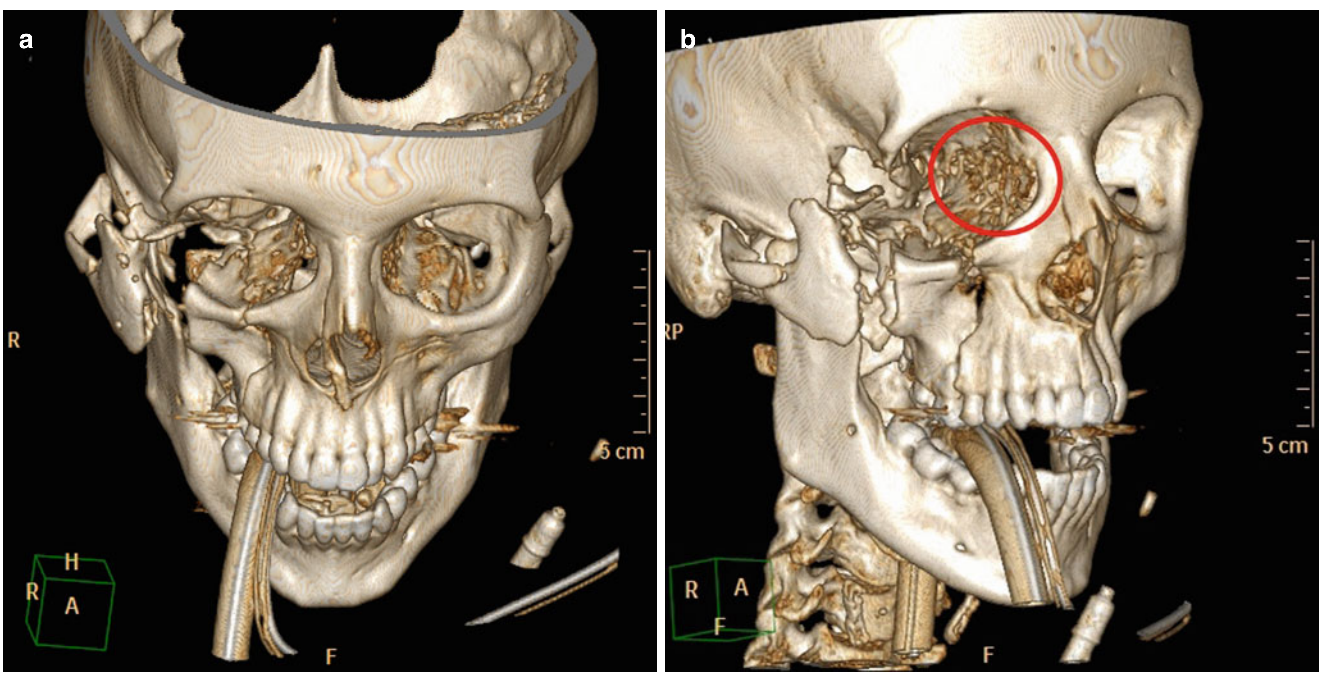

Fig. 11.26 Overview of injuries sustained (**a**, **b**). Although these scans clearly show the extensive fractures to the zygoma, they do not detail the injuries to the NOE region. The medial orbital wall appears to be fractured but on 3D scans this is an unreliable finding. *Red circle* indicates the area of disruption of the medial canthus. In this case the detached tendon does not feature on the 3D CT image

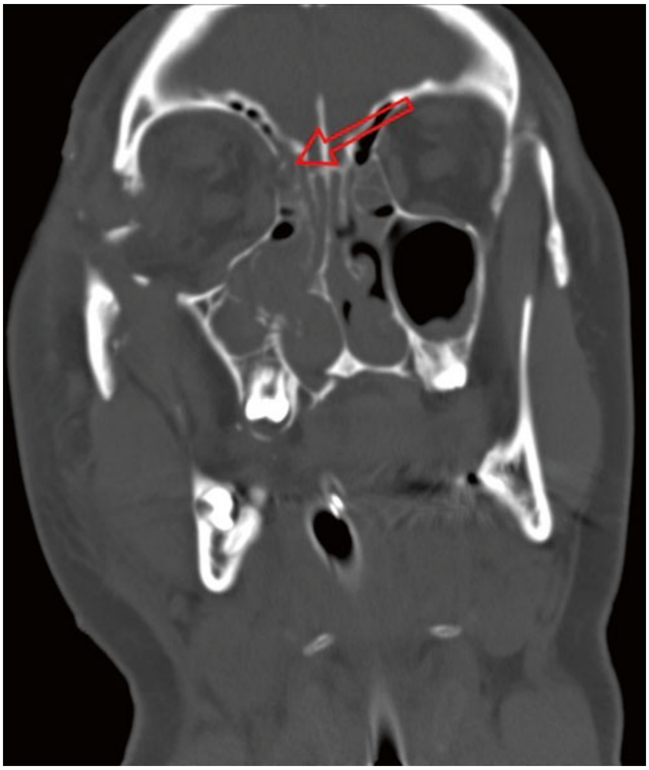

Fig. 11.27 Fine-cut coronal and axial scans are essential to evaluate NOE injuries. The medial orbital wall was fractured with multiple small fragments. Although this was not an extensive NOE fracture, the obvious detachment of the canthal tendon (*arrow*) and associated comminution effectively made this a Markowitz type 3 canthal injury

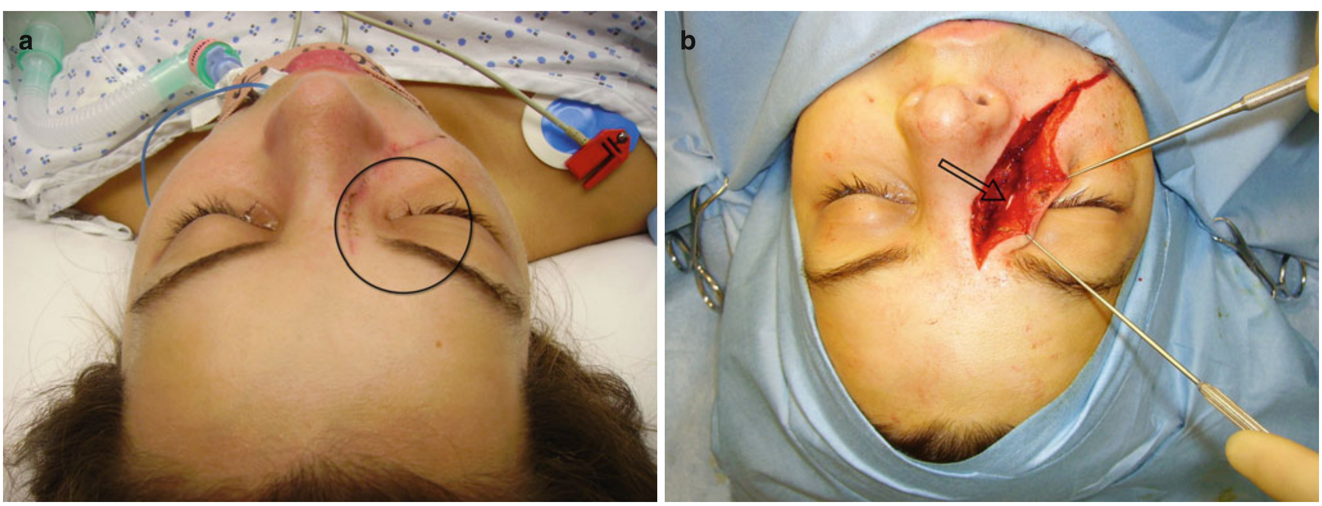

Fig. 11.28 Repair of the ZMC was undertaken through a “3/4” coronal flap (exposure of the opposite ZMC was not required) and an intraoral approach (**a**, **b**). The infraorbital rim, orbit and canthus were approached via the laceration. *Black circle* shows the unilateral telecanthus. The *black arrow* the detached medial canthal ligament

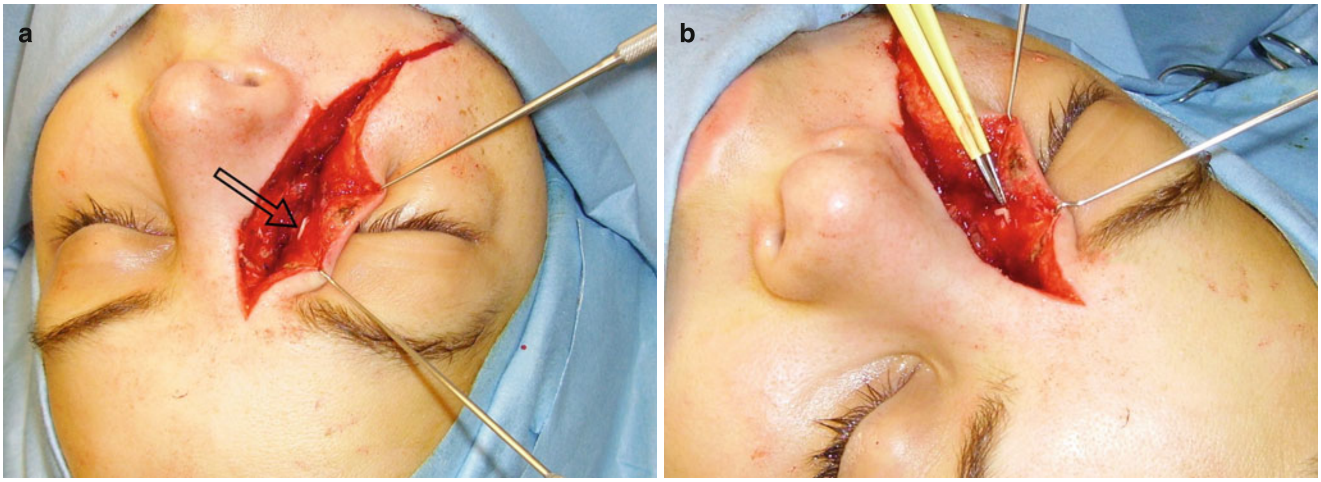

Fig. 11.29 The canthal tendon (*arrow*) was easily identified (**a**). Gently tugging on this structure while observing the canthus externally verified this was part of the tendon (**b**)

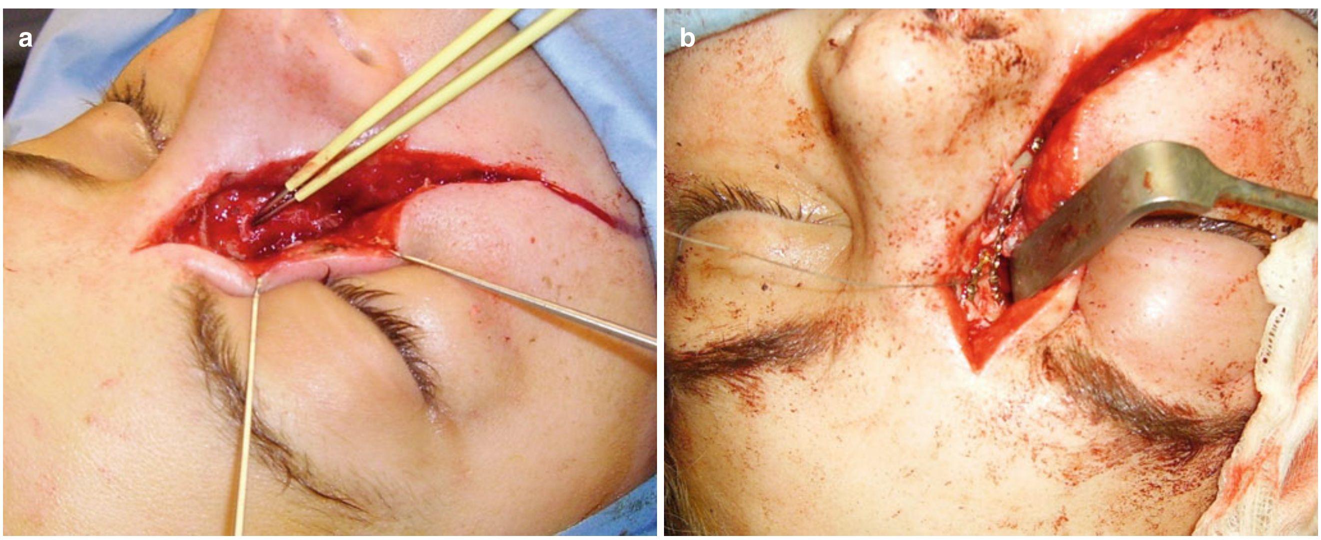

Fig. 11.30 The bone at the desired point of canthal reattachment was comminuted and unable to support a direct repair (**a**). Therefore following repair of the ZMC a rigid plate was secured to the solid nasal bridge and adapted to lie along the medial orbital wall (**b**), such that one of its holes corresponded to the point of reattachment (it was then adjusted to allow over reduction)

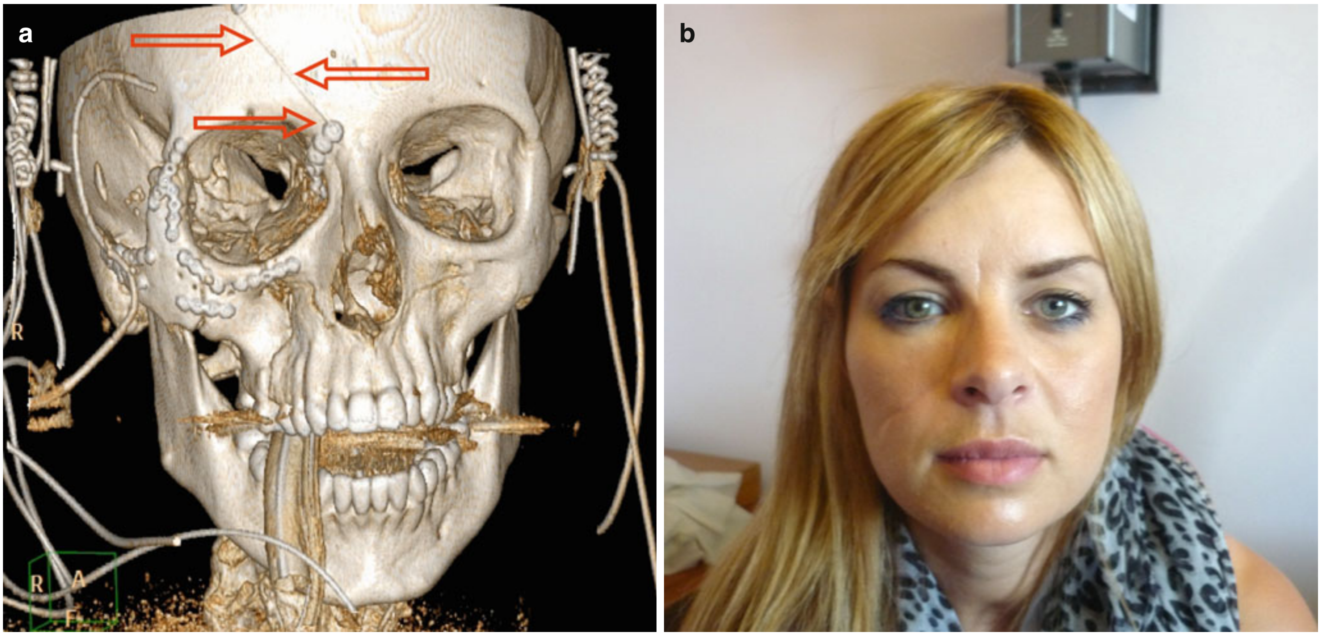

Fig. 11.31 The canthus was secured to the plate using a wire which itself was anchored to the forehead. (**a**, **b**) Postoperative appearances at 2 years (note also ocular implant with shell). The *red arrows* show the canthal tendon wire

Case 2

Fig. 11.32 This patient sustained extensive NOE fractures following a high-energy impact. There was significant bleeding in the resuscitation room requiring urgent airway protection and haemorrhage control (**a**, **b**)

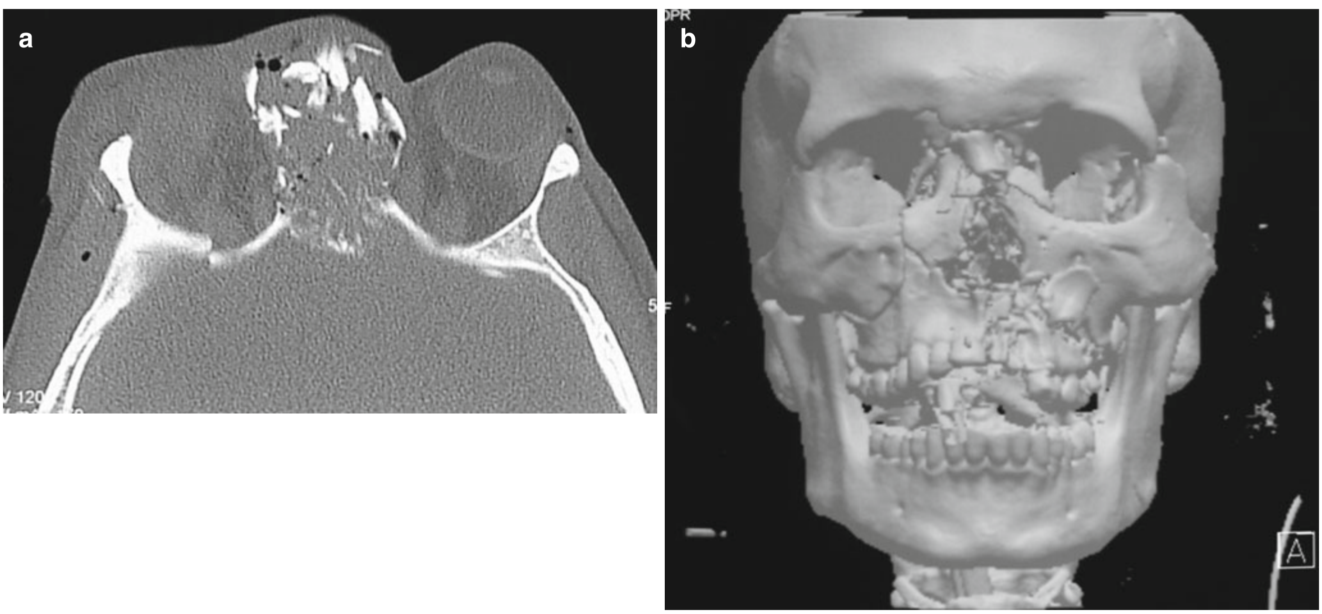

Fig. 11.33 CT clearly shows the highly comminuted nature of this injury, which extends into both orbits and maxillae (**a**). The left zygoma was also fractured. The frontal sinus/skull base were not significantly injured (**b**)

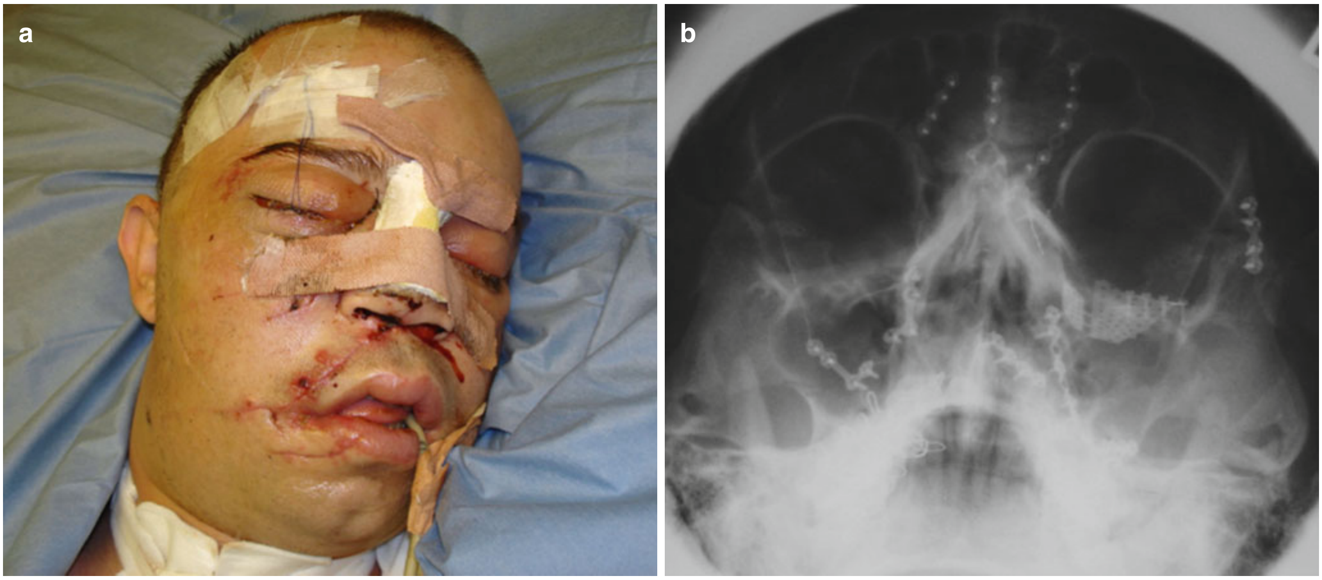

Fig. 11.34 Access to the injuries was possible through the overlaying lacerations. The midface/zygomatic buttresses were repaired and the left orbital floor reconstructed (**a**, **b**). The canthus was found to be attached to a reasonably large fragment, making this a Markowitz type 1 injury. Septal splints were placed

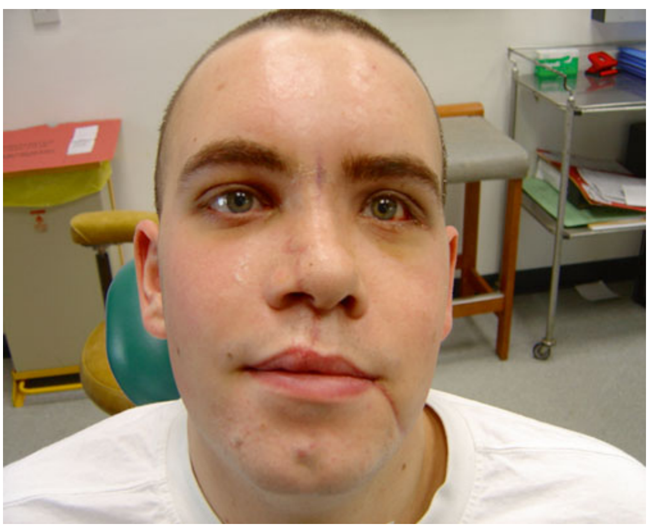

Fig. 11.35 Postoperative appearances. There is residual deformity around the canthus and nasal tip deflection. These are not surprising in view of the extent of injury sustained. The bones are in a good position—and therefore this is predominantly a residual soft tissue deformity

Case 3

Fig. 11.36 This patient was struck on the nose by a "rubber bullet," resulting in a localised high-energy impact (**a**). The left globe was injured and could only perceive light (**b**), but surgery was not contraindicated

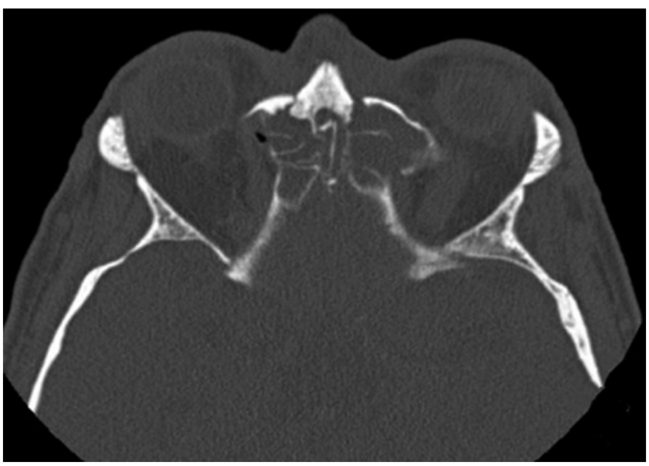

Fig. 11.37 CTs demonstrated a grossly impacted nasal bridge with comminution of the medial orbital walls. Clinically the canthi appeared attached to the bones. Frontal sinus drainage was clearly affected by the collapsed nasal and ethmoid bones, but the anterior cranial fossa was otherwise intact. There was no CSF leakage

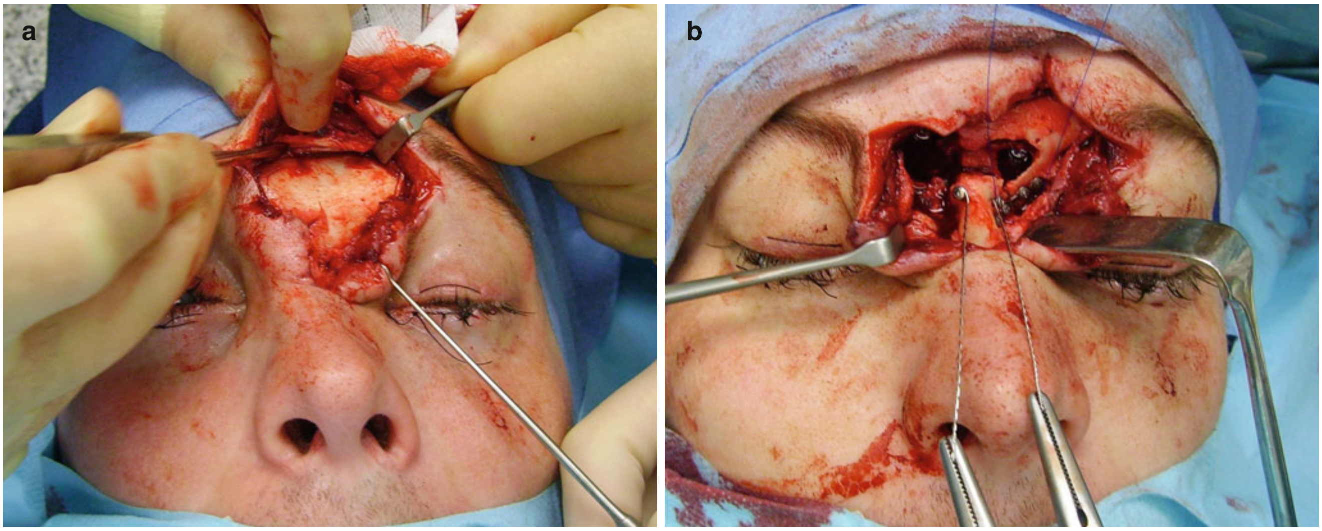

Fig. 11.38 In view of the localised nature of the injury, repair was possible through the overlaying laceration (**a**). This was extended 1 cm to the right in a suitable skin crease, providing very good access. The fractures were carefully exposed (**b**). Loose fragments were temporarily removed to allow inspection of the frontal sinus and evaluate its drainage. The nasal bones were heavily impacted and required a "draw wire" to disimpact them, as shown. Once disimpacted, the drainage pathway of the frontal sinus was inspected and reestablished by removing all loose fragments of bone. Patency was confirmed endoscopically

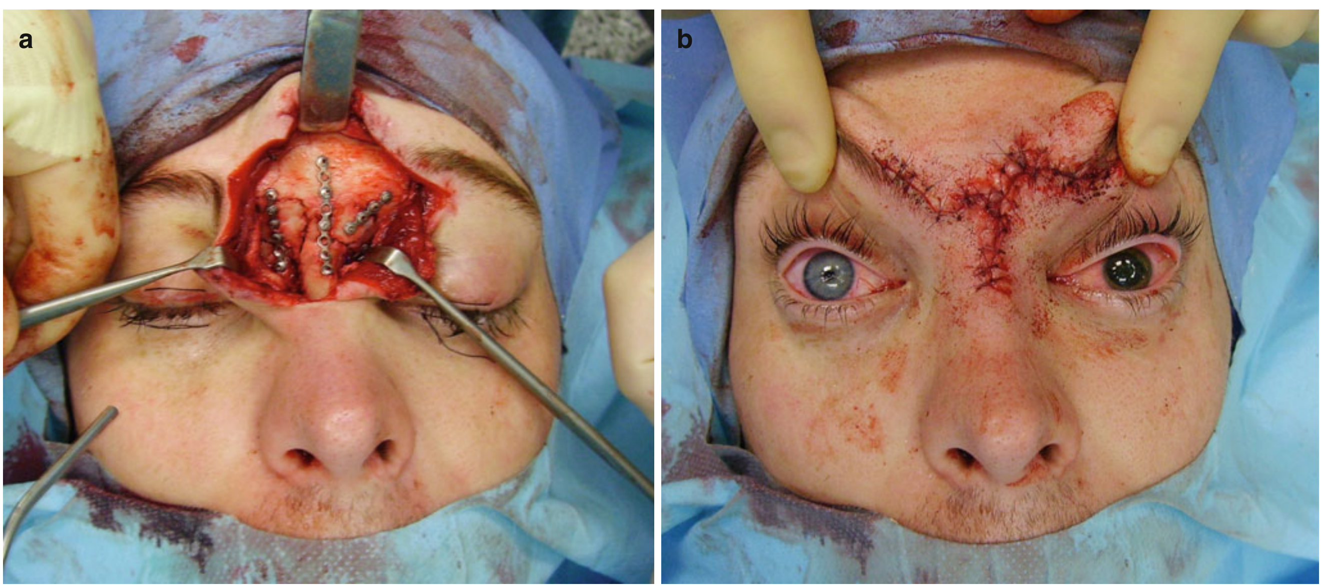

Fig. 11.39 The fragments were then replaced and secured (**a**, **b**). The canthi were attached to adequately sized bones, which received open reduction internal fixation (ORIF) through the wound. The medial orbital walls were also explored through the incision and verified as adequately aligned. No grafting was required

11.5.2 Canthal Access Through Local Incisions

Access to the medial canthal region does not always require a coronal flap. This is best indicated in complex and extensive fractures where access to much of the upper facial skeleton is required. With isolated injuries to the medial canthal region, sufficient access may be possible through local incisions. The decision to repair canthal injuries through local incisions thus depends on a number of factors (the choice between small scars on the face or a much more extensive procedure, the extent of injuries and patient preferences, etc.). A number of local incisions are possible. In the first example, a simple curvilinear incision placed on the side of the nose just in front of the canthal region provides limited, but sufficient access to repair the localised fracture. A full-thickness skin incision was initially made. The underlying muscle fibres were gently separated to expose the underlying bone. The periosteum was then incised and elevated. This simple approach is best suited for localised injuries in which fracture repair is required rather than canthal tendon reattachment (Markowitz type 1 fractures).

Case 1

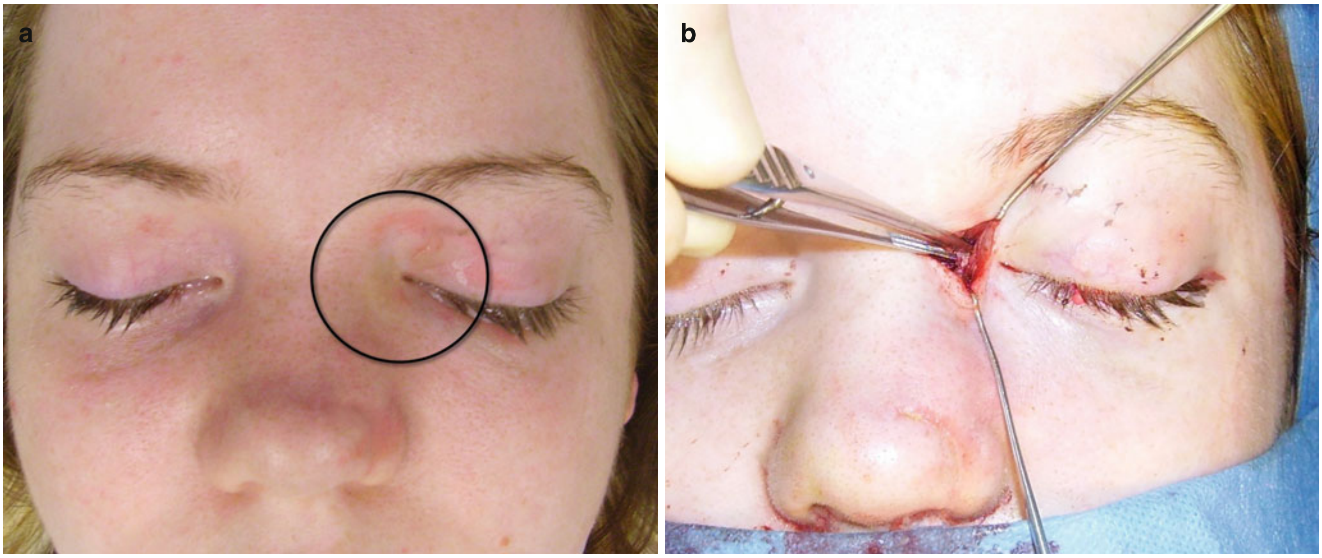

Fig. 11.40 This patient was struck on the nose with a hockey stick resulting in a unilateral, but localised fracture to the nasal bones (**a**, **b**). The mobile fragment carried the canthal attachment and both had drifted laterally. The limited extent of injury was confirmed by CT. The *black circles* are showing the disrupted canthal tendons

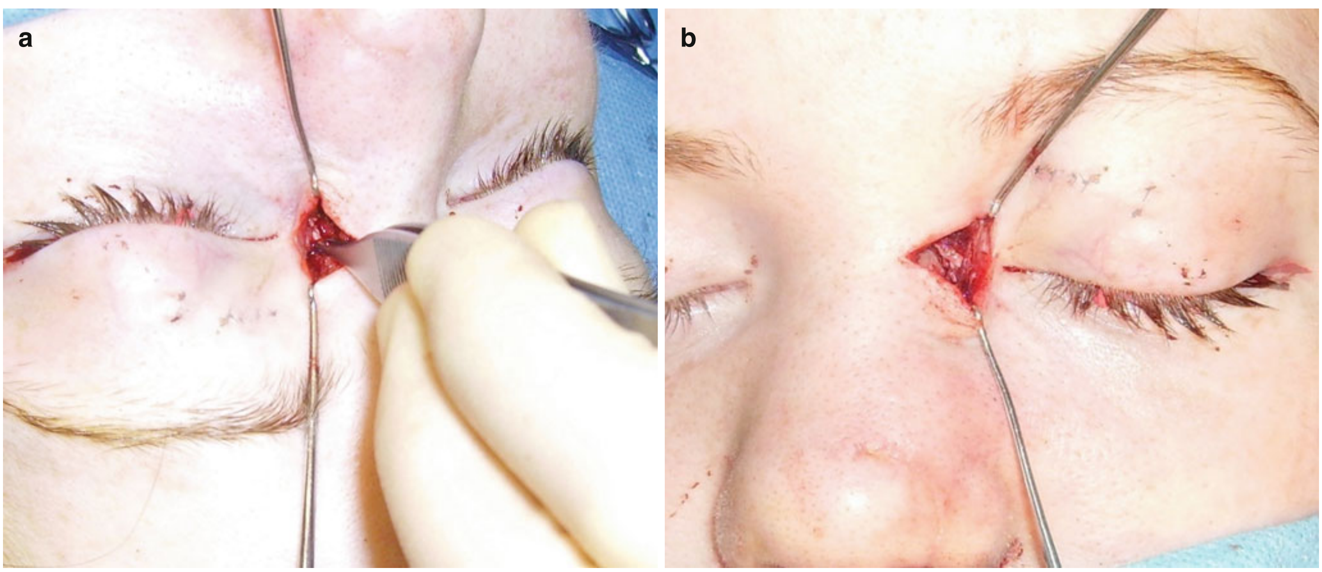

Fig. 11.41 Sufficient access was possible through a small curvilinear incision alongside the nose (**a**). The muscle fibres were gently separated and the periosteum incised and elevated (**b**). The fragment was then plated. Access through such an incision is somewhat limited, but a coronal flap would have been an excessive alternative and would probably not have provided any better access. Through the incision a canthal hook was passed (described later), such that it engaged the tendon. The wire was passed through the hole of a Y-shaped plate

In the next example, slightly more access was required but still did not require a coronal flap. The curvilinear incision just described was converted to a zigzag configuration to improve scar cosmesis. A second incision was required in the subtarsal region medially to access the lower end of the fracture. This latter incision required splitting of the underlying muscle fibres and careful dissection to avoid the lacrimal drainage apparatus. The fractures were fixed and the canthal tendon was further supported by securing it to a cantilevered plate with a canthal wire (described later).

Case 2

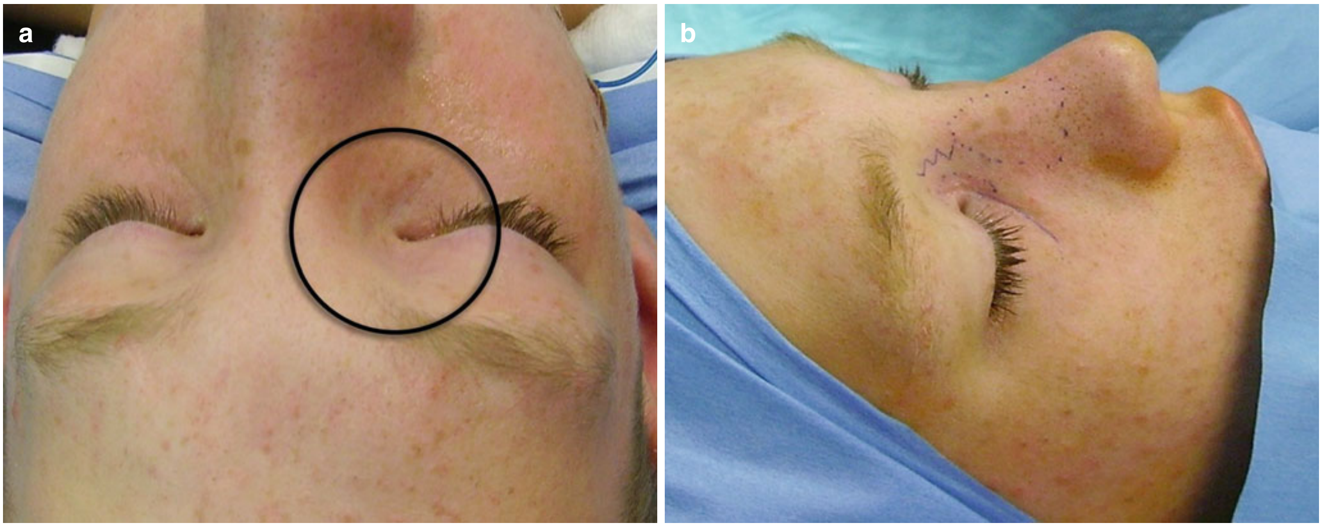

Fig. 11.42 Unilateral NOE and nasomaxillary fractures following a localised injury (struck by a cricket ball) (**a**, **b**). CTs confirmed a localised injury with minimal involvement of the medial orbital wall. However, the canthus was attached only to medium to small size fragments and had drifted laterally. Access was planned through a zigzag nasal incision and by extension of the small medial subtarsal wound. This required careful dissection to avoid damage to the lacrimal drainage system. The *black circles* are showing the disrupted canthal tendons

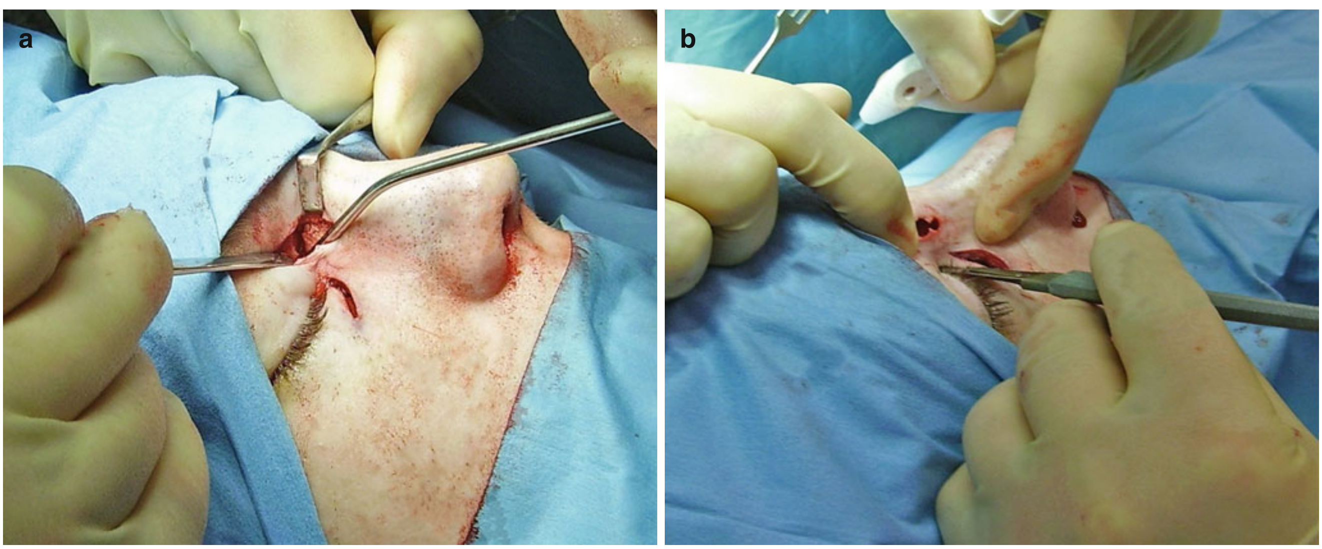

Fig. 11.43 The nasomaxillary fracture was reduced and plated (**a**, **b**). The canthus was attached to small fragments of bone only. A small stab incision was placed over the canthal tendon

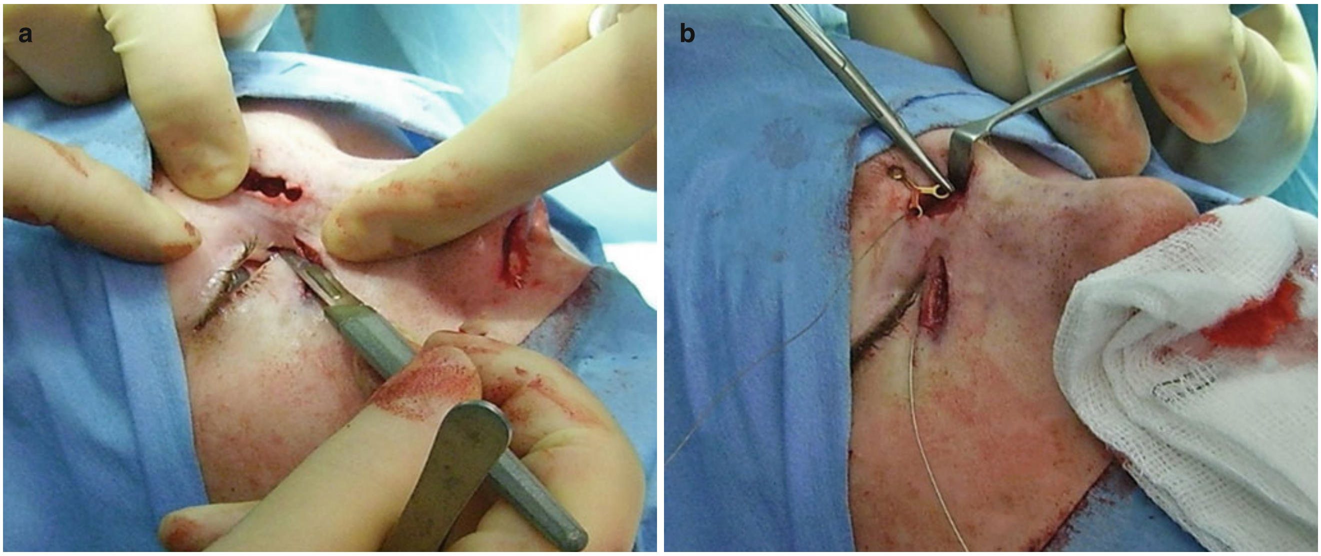

Fig. 11.44 Through the incision a canthal hook was passed (described later), such that it engaged the tendon (**a**). The wire was passed through the hole of a Y-shaped plate (**b**)

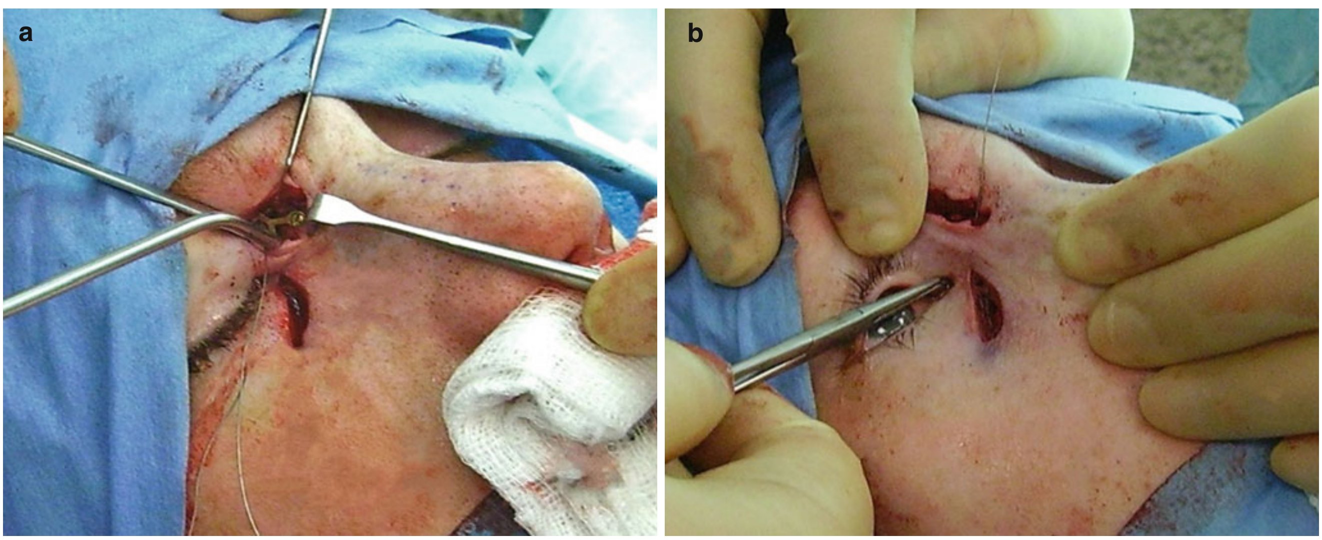

Fig. 11.45 The plate was then cantilevered, adapted and secured to the nasomaxillary bones such as to tether the canthus to the desired position (**a**, **b**). The wounds were closed in layers. Plate selection is important. These must be rigid enough to withstand traction forces following closure. Otherwise the canthus will drift as the plate deforms

Under the right circumstances, the cantilevered technique can work well, but it does require sufficiently rigid plates. Otherwise the plate simply deforms, allowing the canthus to drift laterally. It also requires structurally solid surrounding bones to which the plate can be secured. This technique has the advantage of avoiding exposure of the opposite canthus. The principle is simple: the plate is secured in such a fashion that it lays along the medial orbital wall, such that one of its holes coincides with the point of canthal attachment. The canthus is then secured to the plate rather than directly to bone.

11.5.3 Canthal Fixation Directly to Bone

Alternatively, direct fixation of the canthus to the bone may be achieved using a number of different techniques. Transnasal canthal fixation requires exposure of the opposite side and is therefore best suited for bilateral (and usually extensive) injuries. Access is usually through a coronal approach. With bilateral injuries, both canthi are engaged by a suture (nonresorbable or wire) which passes through the nose. Each canthus therefore provides reciprocal support for the other. If bone is missing, grafting or a plate may be required to provide additional support. Overcorrection is recommended (see Fig. 11.46).

Variations of this technique can be used when repairing unilateral fractures, but they still require exposure of the opposite side to some degree (see Fig. 11.47).

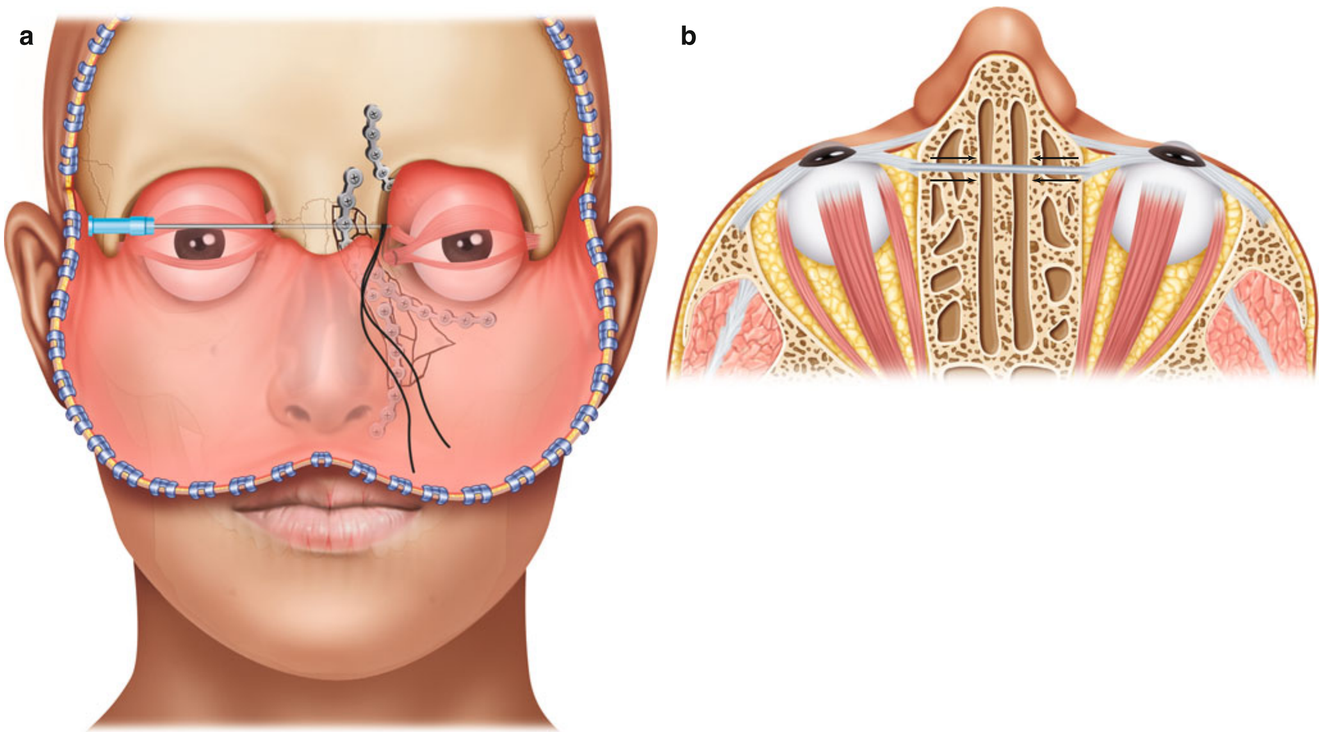

Fig. 11.46 Transnasal canthopexy. The suture engages both canthi (**a**), passing through the nasal cavity from one side to the other (**b**). Overcorrection is required

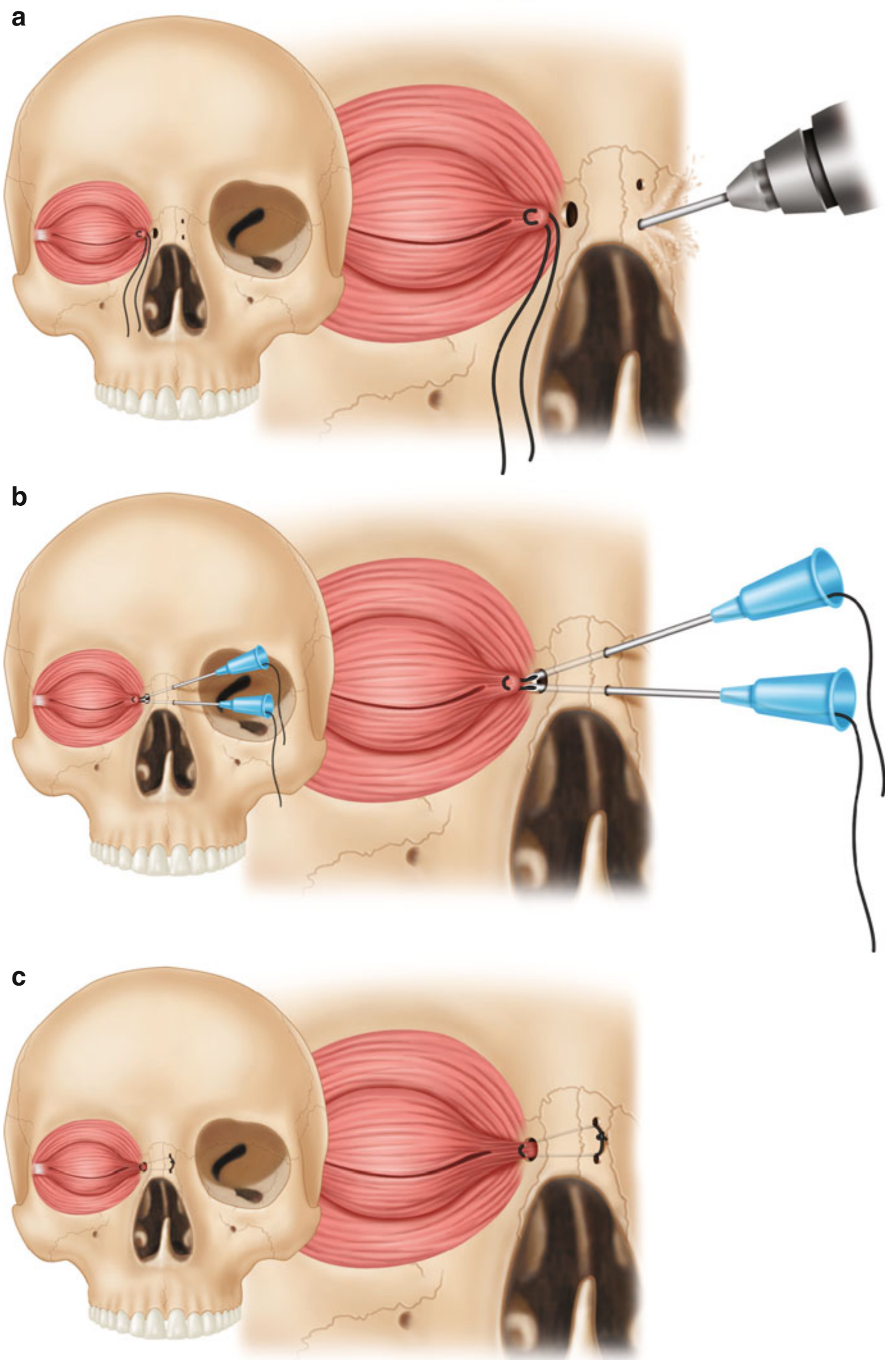

Fig. 11.47 Transnasal canthopexy for unilateral canthal injuries. Holes are drilled through the nasal bones (**a**) through which the suture ends can be passed (**b**) and tied (**c**)

11.5.4 Unilateral Canthal Attachment Directly to Bone Using a Wire Hook

In the case shown, direct fixation to the bone was possible without a cantilevered plate. A coronal flap was required to expose the patient's extensive facial injuries. The medial canthus had been completely detached from bone with only a few small fragments to help relocate its position precisely. Fixation of the canthus was therefore undertaken using a "canthal hook." This is essentially a wire suture with a small "anchor-like" barb on the end (see Fig. 11.48).

Following repair of the fractures, the needle of the wire was initially passed transcutaneously (through a small incision), to enable the hook to engage the medial canthal tendon. The point of canthal reattachment was carefully determined using the opposite side as a guide. A hole was then drilled into the upper nasal cavity. The leading end of the wire was passed through into the nasal cavity, grasped with a long clip and fed out through the nose. A second small hole was then drilled through the bridge of the nose, through which a long curved hollow trochar needle was passed into the nasal cavity and out through the nose. Its lumen was used as a guide to facilitate passage of the wire back through the second hole. Following adjustment of the canthal position the wire was then secured to frontal bone using a small screw (see Figs. 11.49–11.56).

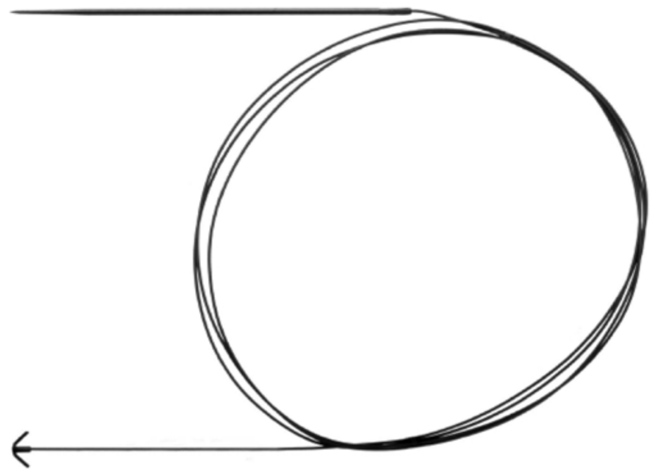

Fig. 11.48 Canthal hook (canthal wire). This is a wire suture with a needle at one end and a small barb or "hook" at the other. The hook engages the canthal tendon. This provides secure fixation, although tearing of the tissues can occur if it is placed under excessive tension during overcorrection

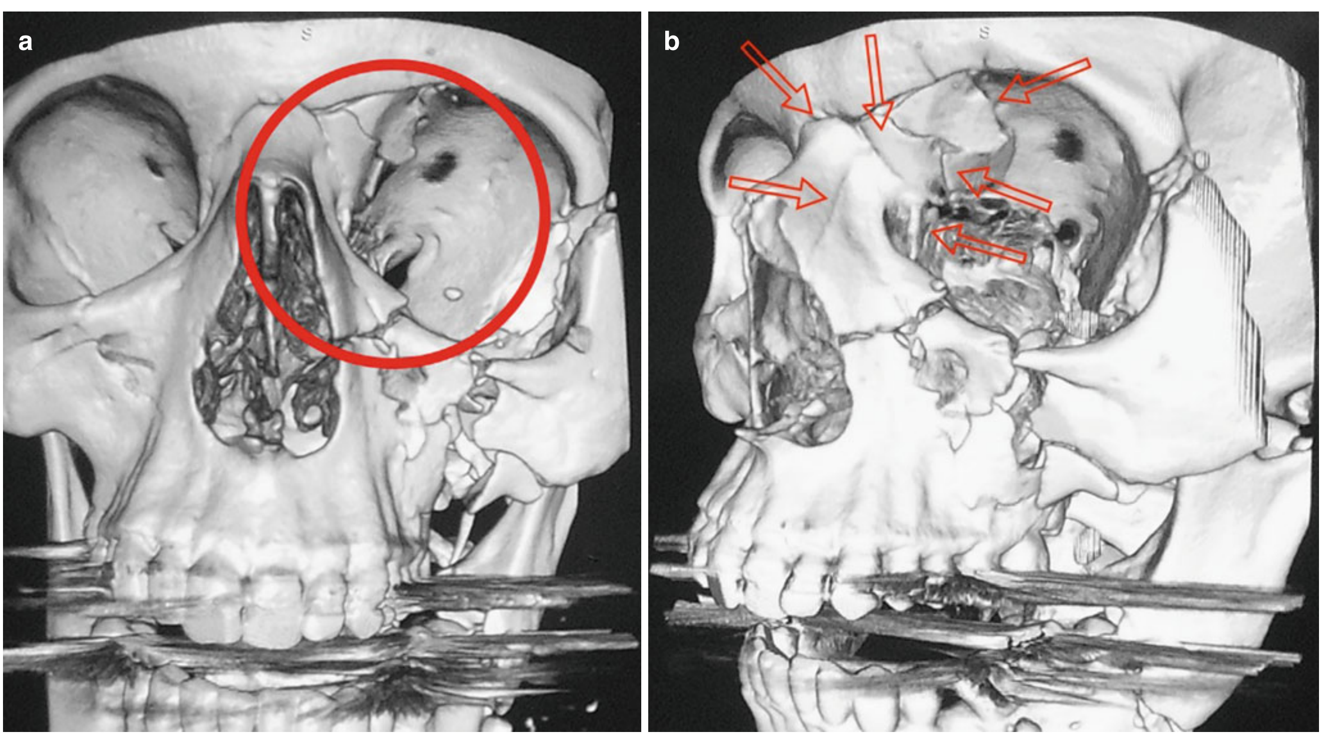

Fig. 11.49 Extensive fractures to the left side of the face with comminution of the left NOE region (**a**). The medial canthus (*red circle*) was attached only to a few small fragments (**b**). The *red arrows* define upper limit of fractures extending into frontal sinus and orbital roof

Fig. 11.50 The canthus is seen to be drifting laterally at repair, 7 days later (**a**). Following repair of the facial fractures a small incision was made in the overlaying skin (**b**)

Fig. 11.51 The needle of the canthal wire was then passed through the incision allowing optimal engagement of the canthal tendon by the hook (**a**). The point of attachment to the bone was determined and a small hole drilled into the nasal cavity (**b**) (this was overcorrected by siting further posteriorly)

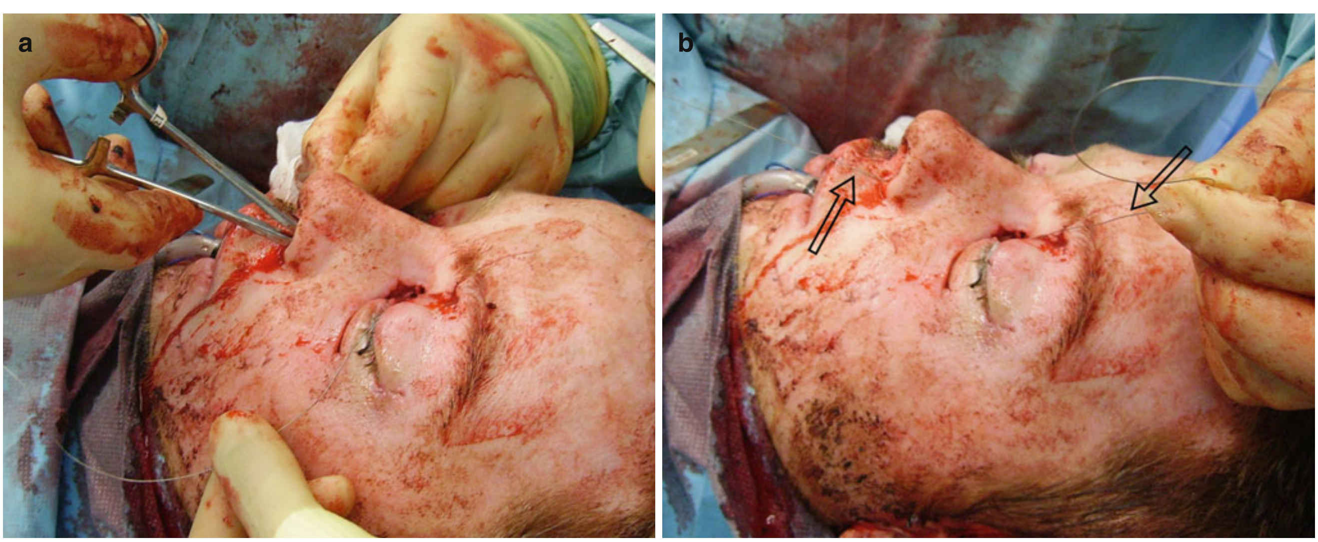

Fig. 11.52 The end of the wire was then passed into the nasal cavity (**a**) and retrieved (**b**)

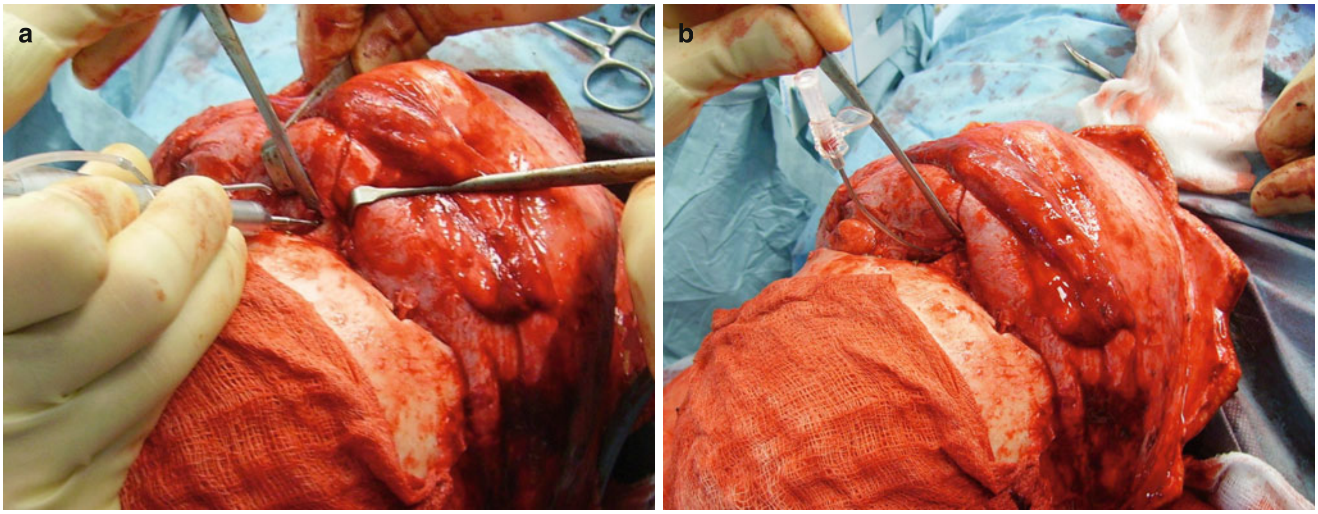

Fig. 11.53 A second hole was drilled through the nasal bridge into the nasal cavity (**a**). A long metal cannula was bent to shape and passed through the hole and out the nostril (**b**). The end of the wire was then thread through the lumen and out the second hole

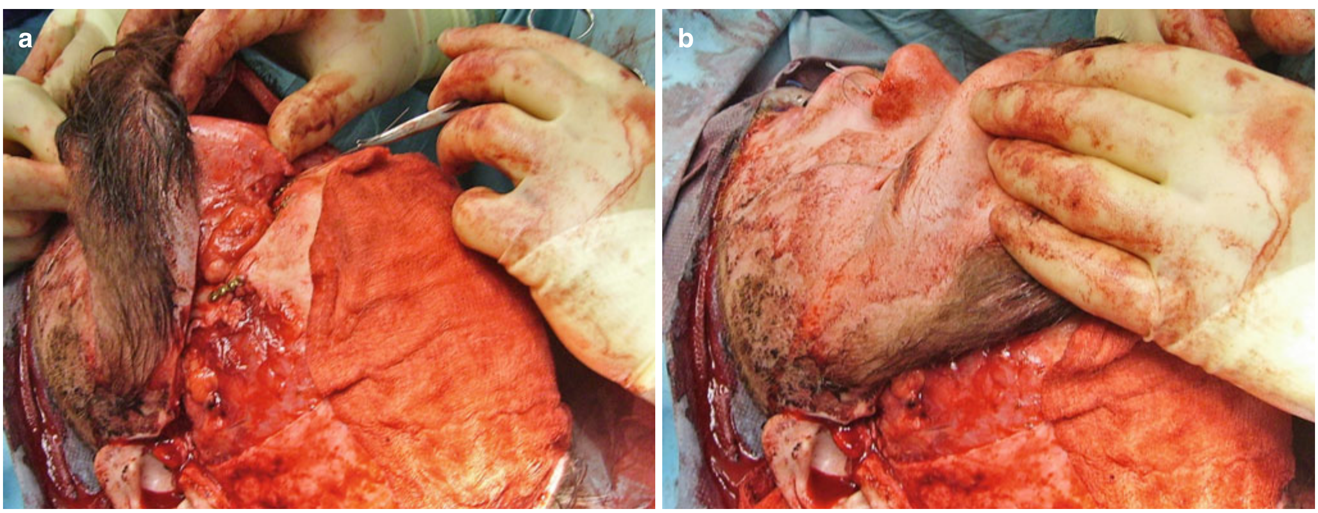

Fig. 11.54 The tension on the wire was gradually adjusted (**a**, **b**)

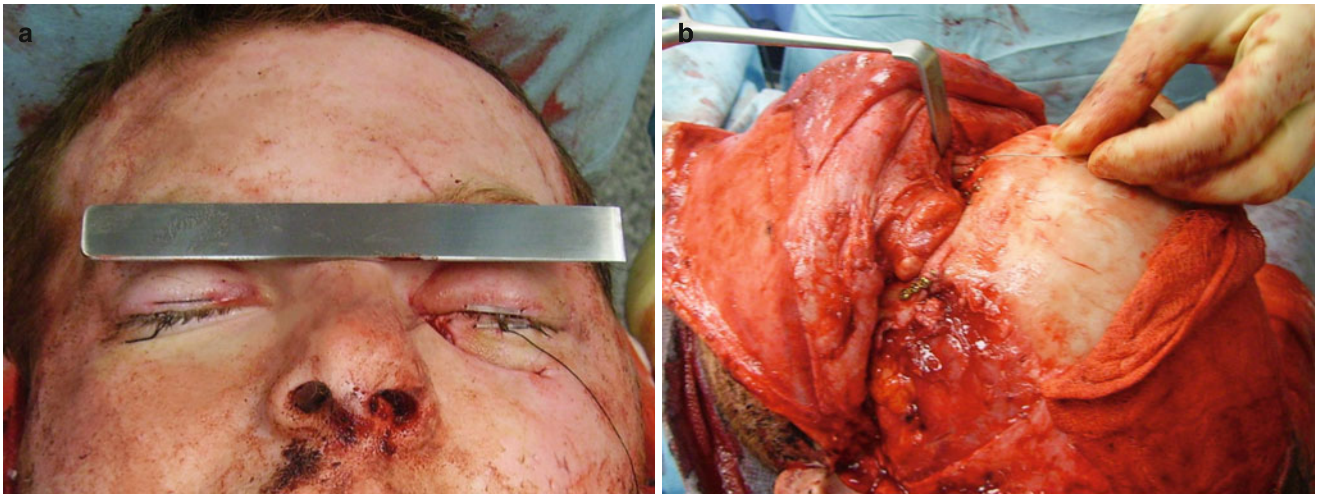

Fig. 11.55 The ICD was measured (**a**) prior to fixation of the wire to the forehead (**b**) (this was also overcorrected)

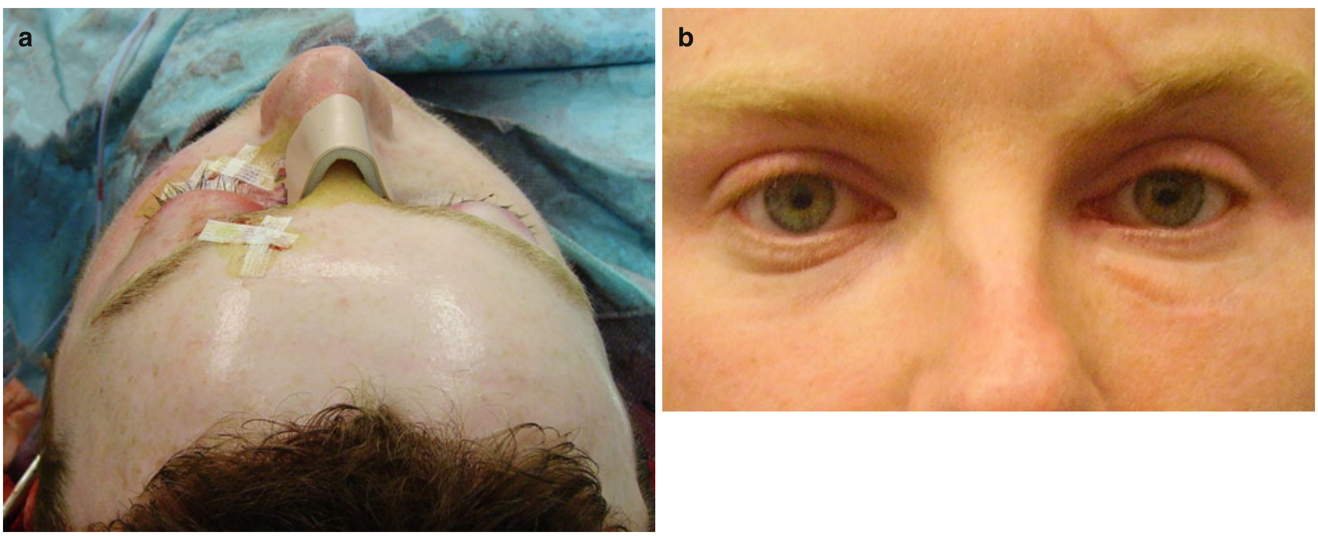

Fig. 11.56 Supplementary external support was placed to maximise soft tissue draping (**a**). Postoperative appearance at 6 months (**b**)

Reattachment of the canthal tendon to bone is also possible using a "Mitek" tendon suture. This device is best used when the canthus has been completely detached from the underlying bone, which itself is undamaged. The Mitek suture is commonly used in hand surgery to reattach tendons to the phalanges. This devise is composed of a small pin which is anchored to the bone, attached to which are two small sutures. The needles at the ends of the sutures are then passed through the tendon and tied. These sutures are usually made of a resorbable material but it is possible to replace them with a non resorbable suture.

In the case shown, access to the medial canthal region was through a coronal flap. The position of reattachment was determined by comparing to the noninjured side. To help locate the point of attachment on the bone, a large needle was passed transcutaneously through the repositioned canthus, onto the bone and held in position while the coronal flap was then turned down. The tip of the needle helped identify where the canthus should be attached (overcorrection is again recommended). Once the point of attachment was confidently located, a small hole was drilled into the bone (a drill is supplied with the Mitek suture). The device was then loaded and the pin pressed firmly into the drill hole. This is a one-off mechanism and cannot be repeated if the position is wrong. The pin has two spring-loaded hooks which engage the undersurface of the bone, preventing it from being pulled out (the principle is somewhat like the spring loaded camming devices used in mountain climbing) (see Fig. 11.57).

Once the hook was secured, the needle on the end of the suture was then passed through the canthal tendon and tied (in the case shown the original suture was replaced by a stronger prolene suture).

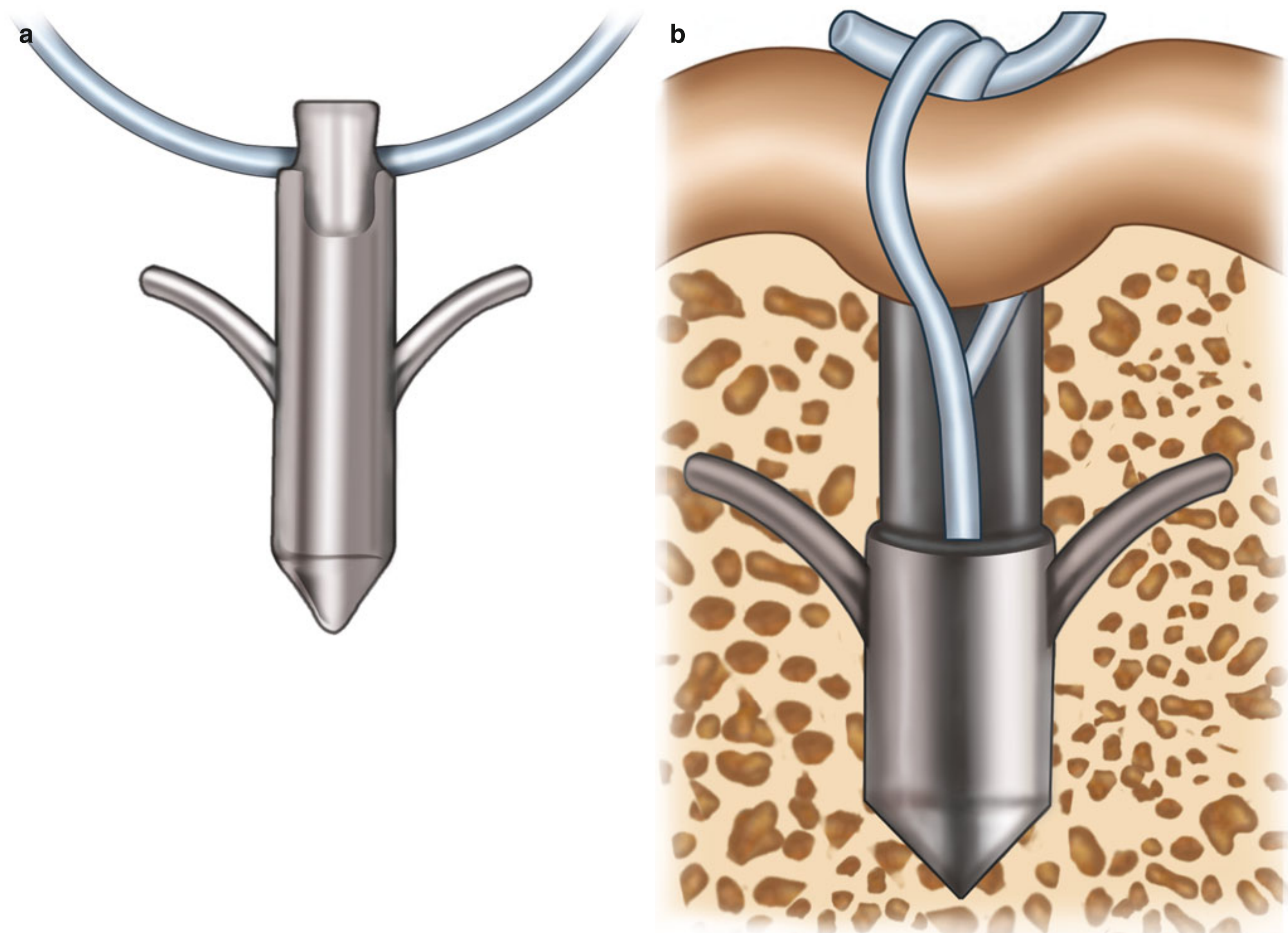

Fig. 11.57 Mitek tendon suture. The spring loaded "barbs" engage the bone thereby anchoring the pin (**a**). Sutures are attached to the other end (**b**)

11.5.5 Canthal Fixation Using a Mitek Suture

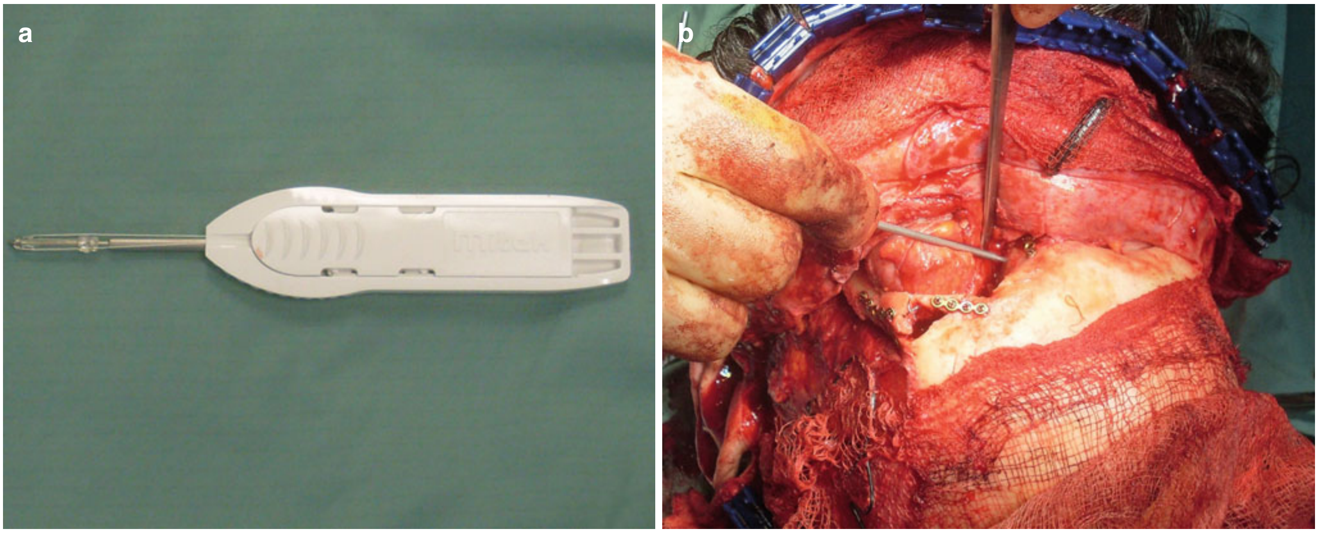

Fig. 11.58 Mitek suture. This is a spring-loaded device (**a**). The position of canthal attachment was determined and marked (**b**)

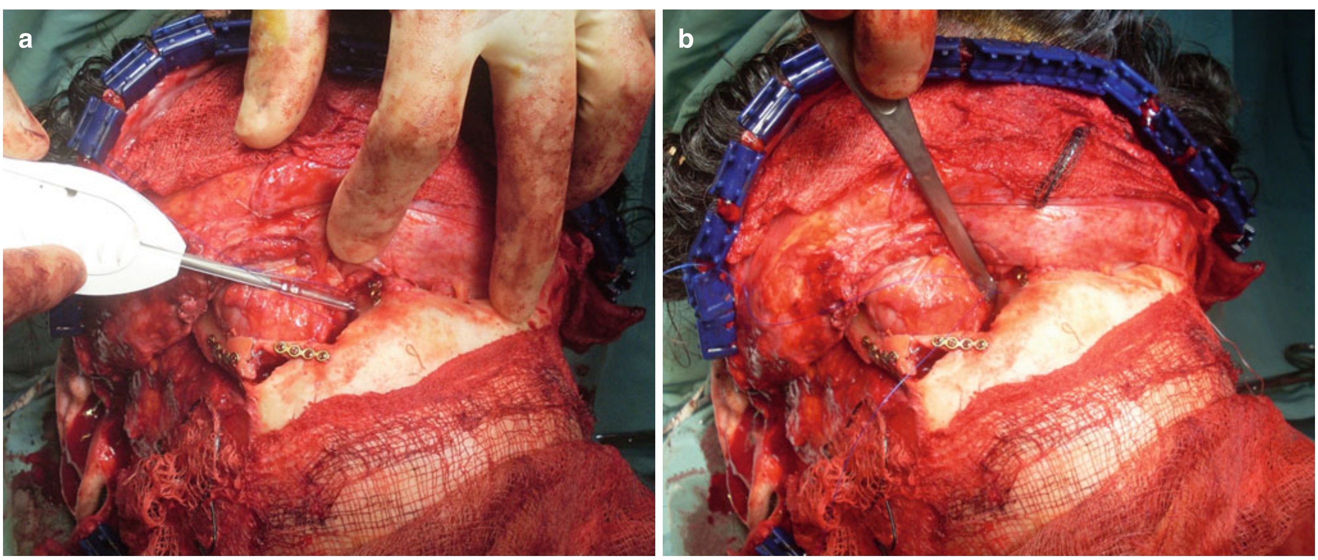

Fig. 11.59 A small hole was drilled and the device activated (**a**, **b**). The pin is pushed into the hole which allows the barbs to spring outwards and engage it. The device is then released, leaving just the sutures

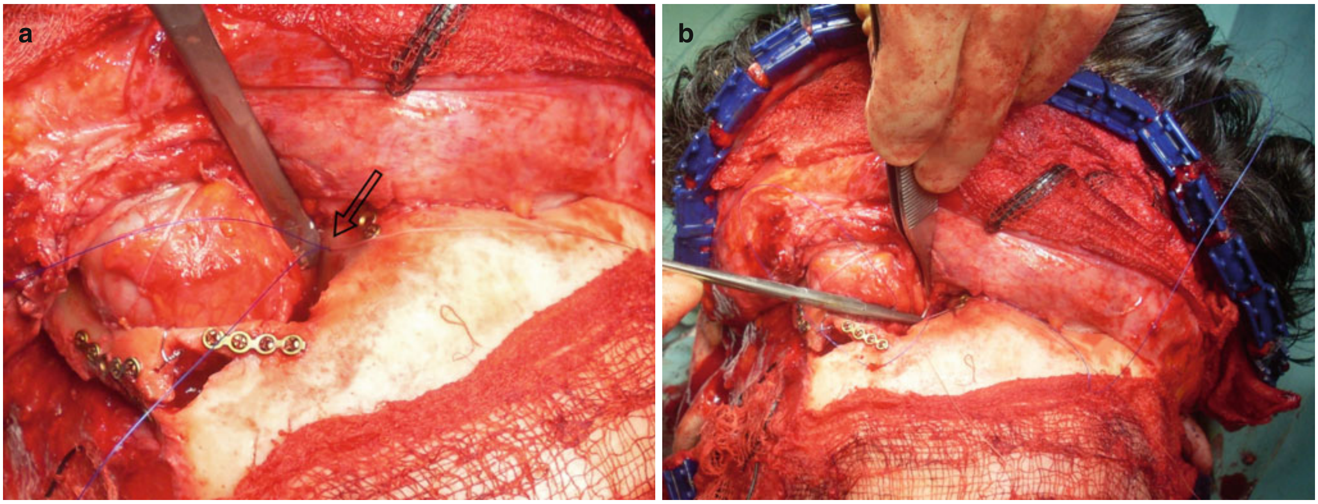

Fig. 11.60 The suture can be seen exiting the bone (**a**). The needle on the other end was then passed through the MCT (**b**)

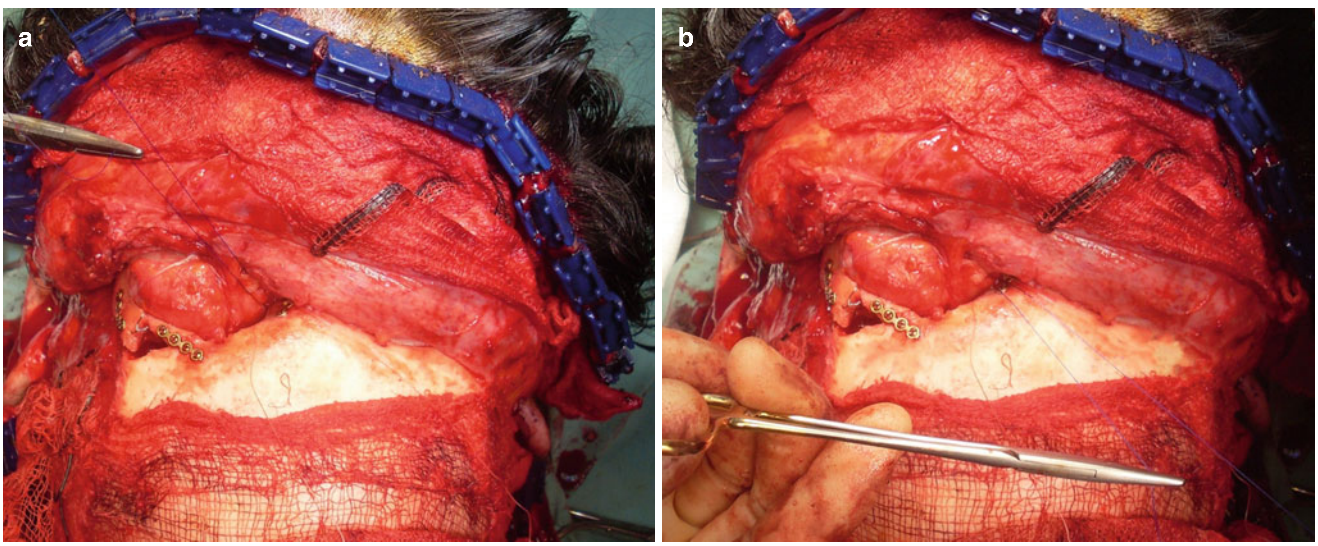

Fig. 11.61 The MCT was adjusted into position (**a**) and the suture tied (**b**)

11.6 Injuries to the Lacrimal Drainage System

The lacrimal apparatus consists of the lacrimal gland, lacrimal puncta (medially on the upper and lower eyelids), their canaliculi, the lacrimal sac, and the nasolacrimal duct (see Fig. 11.62).

These are inevitably affected by NOE injuries, although this can vary considerably. Opinions differ on the need for immediate intervention during repair of the fractures. Although direct injuries to the lacrimal gland and lacrimal sac are rare (each lies within its own protective fossa), injuries to the canaliculi are commonly seen. Blunt trauma can result in persistent swelling and secondary stenosis later as a result of scarring. Lacerations to the medial aspect of one or both eyelids can also lacerate these delicate structures.

Examination may reveal a swollen rounded medial palpebral fissure and lower eyelid laxity. Although epiphora is common, this is an unreliable indicator of lacrimal injury. Lacrimal function may be assessed more accurately with the dye disappearance test (sometimes referred to as the Jones dye test). This has previously been described. Alternatively, the puncta can be gently dilated and inspected. In awake and cooperative patients, the lacrimal system may be gently irrigated with saline. This will result in one of three findings:

1. If the canaliculus is damaged proximal to the common canaliculus, this will result in reflux of the saline out the punctum.
2. If the canaliculus is blocked distal to the common canaliculus, saline will reflux from the opposite punctum.
3. If a canalicular laceration is present, fluid may swell up in the wound or leak out.

Management of lacrimal injuries usually falls under the remit of ophthalmic/oculoplastic surgeons. How canalicular injuries are best managed is controversial and several options exist (see Table 11.5). Some surgeons argue that repair should be undertaken primarily because a scarred lacrimal system cannot be functionally repaired. In these cases repair is undertaken within 48 h although successful repairs have been reported with delays up to 5 days.

Table 11.5 Management options in lacrimal injuries

Observation (if only one canaliculus is injured)
Primary repair with intubation of the upper and lower systems. This can be delayed for 48 h without affecting the outcome
Dacryocystorhinostomy (DCR) or conjunctivo-dacryocystorhinostomy C-DCR at a later date

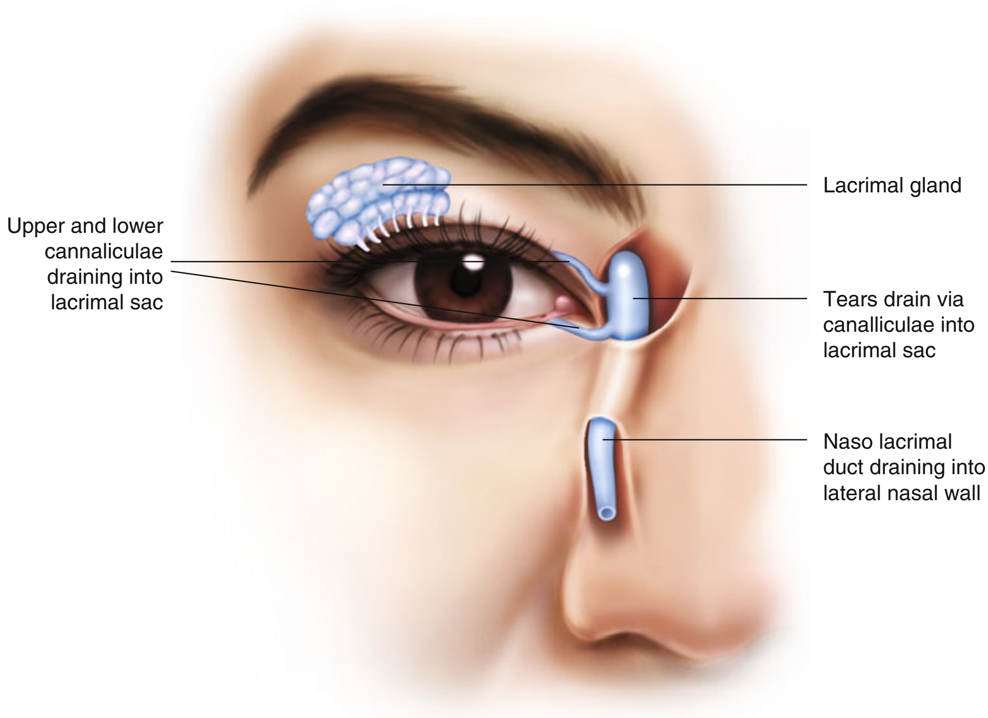

Fig. 11.62 Anatomy of the lacrimal drainage system

Surgical repair is usually carried out under magnification. A silicone stent is passed over a pigtail probe and secured. The canaliculus itself usually does not require repair. Rapid recanalization of mucosal surfaces occurs, but how long the stents should remain in situ is controversial. Some authorities recommend leaving them up to 6 months.

Injuries to the lacrimal sac and duct are very difficult to identify during initial assessment and therefore primary repair is usually not undertaken. These injuries tend to be managed at a later stage with dacryocystorhinostomy (DCR) or conjunctivo-dacryocystorhinostomy (C-DCR). Endoscopic assisted DCR has also been reported with the advantage of no external scarring.

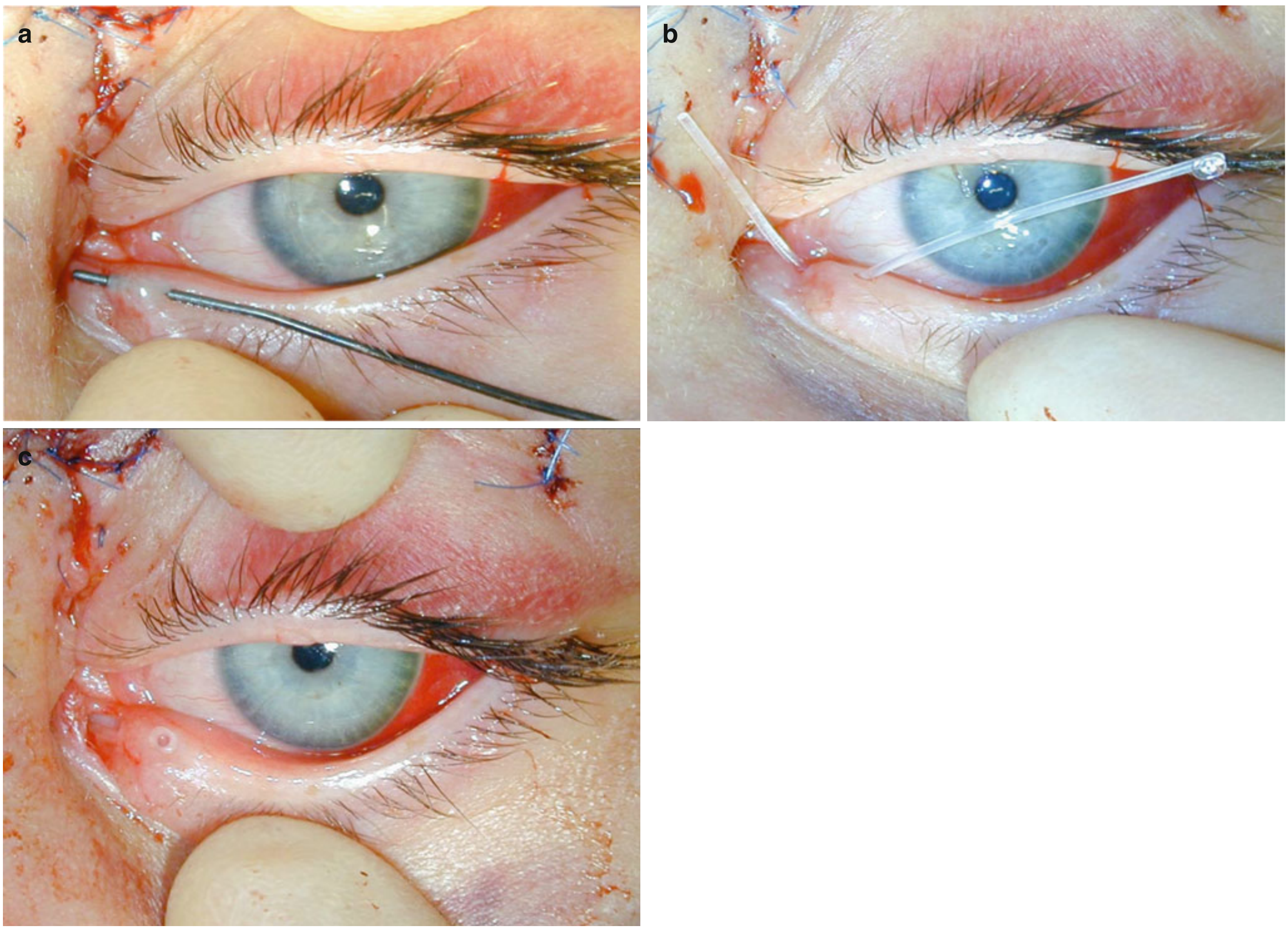

Fig. 11.63 Stenting of a lacerated canaliculus (**a**–**c**) (Niall Kirkpatrick and Nuresh Joshi)

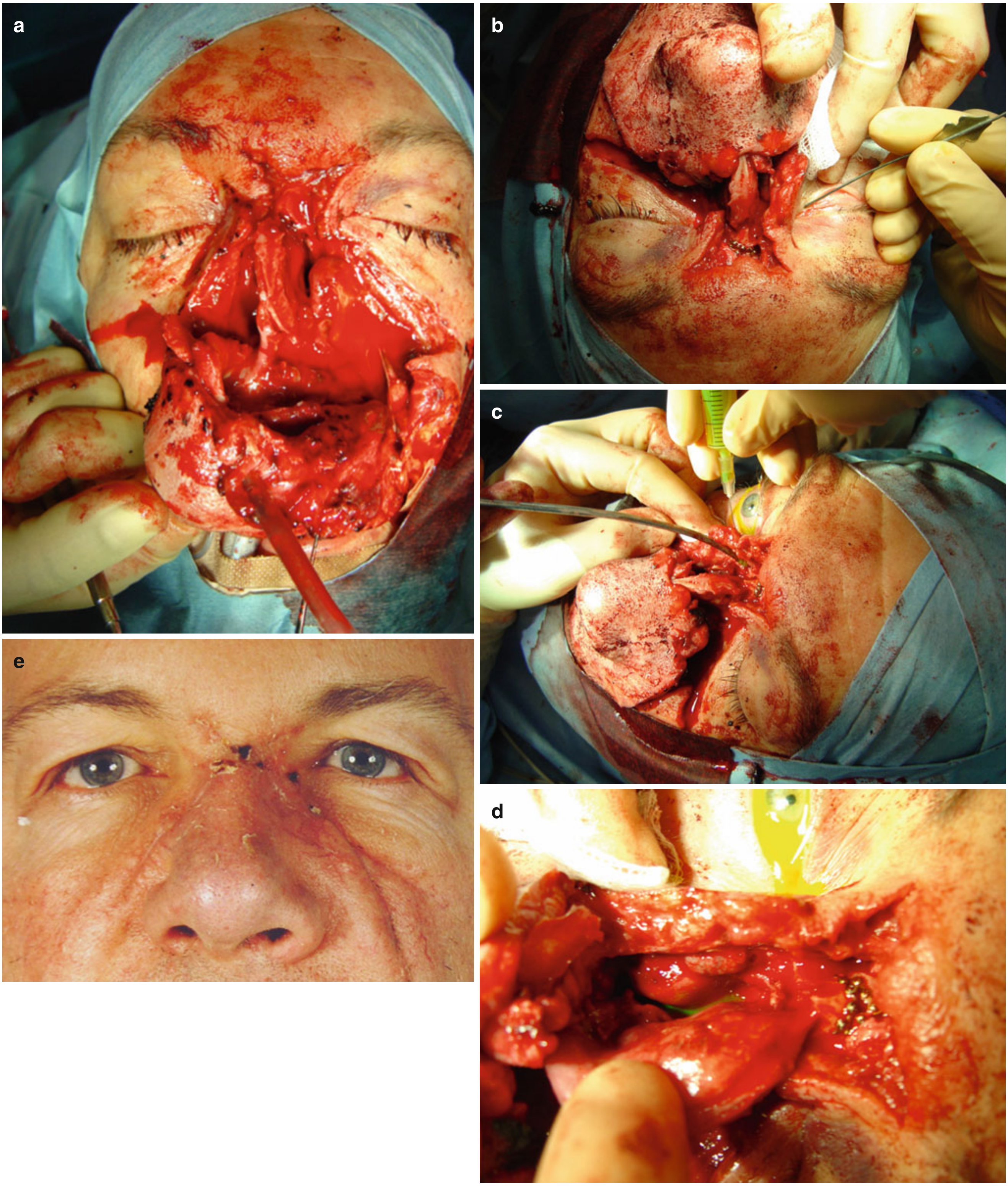

Fig. 11.64 Repair of canalicular injuries at the time of initial fracture repair is controversial. Identification of the canaliculus can be difficult, but not impossible, even with extensive injuries (**a**–**e**)

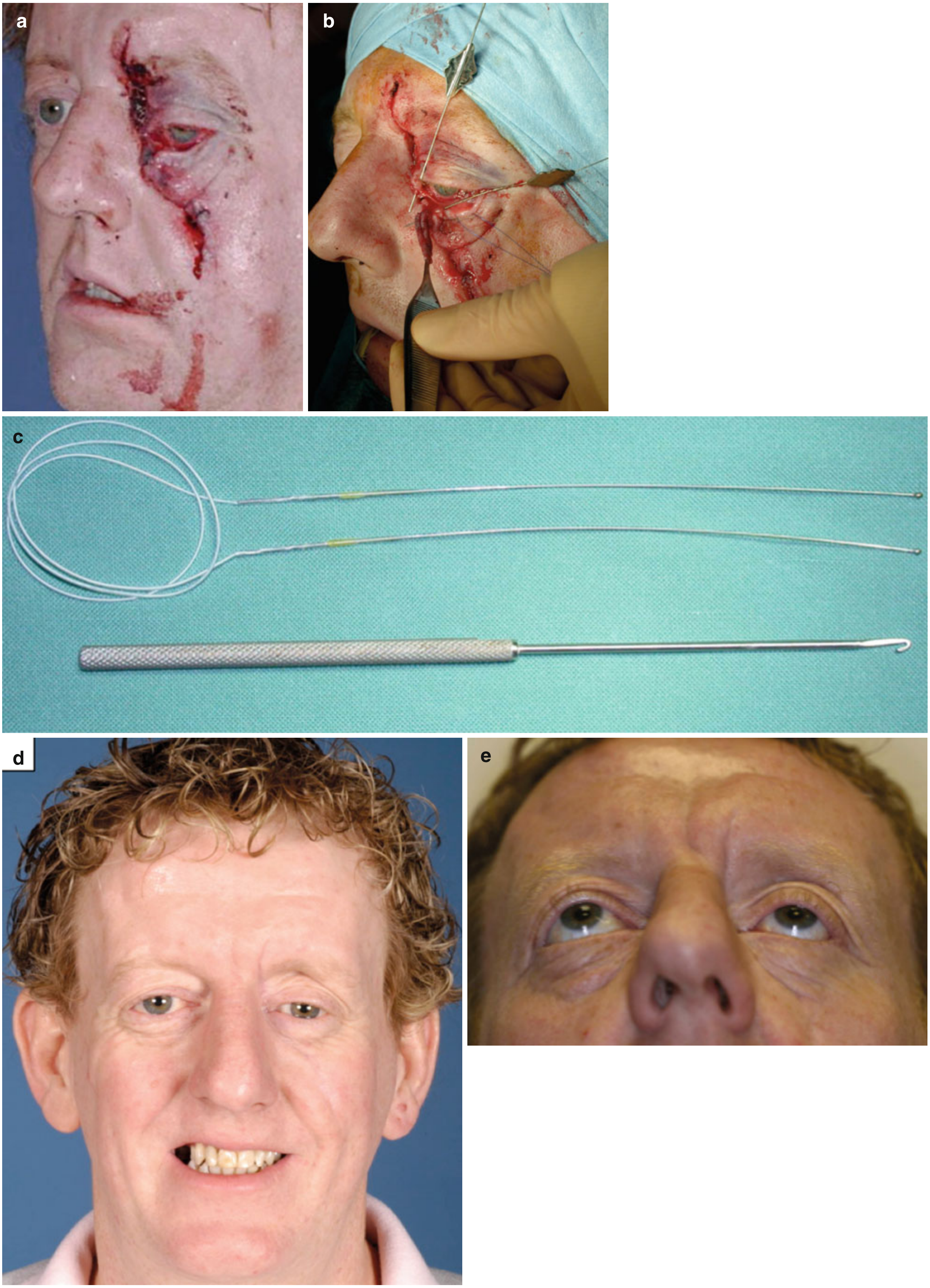

Fig. 11.65 Repair of upper and lower canalicular injuries following extensive sharp trauma (**a**–**e**)

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Panfacial Fractures

12

John Hanratty and Michael Perry

The term "Panfacial fracture" can mean different things to different clinicians. "Pan" (derived from the Greek "πάν" meaning "all," "of everything," or "involving all members" of a group), implies that fractures will be widespread throughout the facial skeleton. As such, they will probably follow high-energy impacts (possibly with associated comminution), or they may follow multiple impacts (commonly seen in assaults). Fractures to the teeth, mandible, maxilla, zygoma, nasoethmoid (NOE) region, orbits and frontal sinus are therefore all possible. When the skull base is seriously disrupted or there are coexisting neurosurgical injuries, the term "craniofacial" fracture is often used.

Because of the large number of fracture permutations that are possible, there is currently no single definition of a "panfacial injury" that will accurately encompass all possibilities. Useful diagnostic criteria may include:

- Fractures which span the occlusion
- Fractures which cross the midline
- Fractures involving the lower, middle and upper thirds of the face
- Multiple fractures following a high-energy impact, or multiple impacts
- Multiple comminuted fractures at multiple sites

With this in mind, it may be helpful to think of these fractures as multiple and complex fractures involving two or more regions of the face, or as high-energy fractures simultaneously involving the upper, middle and lower face. Other definitions exist.

Whatever the diagnostic criteria used, an important and universal feature of panfacial fractures is that they represent significant and often severe injuries to both the bones and soft tissues. Furthermore, due to their very nature, these injuries are commonly associated with coexisting injuries (notably to the cervical spine, brain and visual pathways). Swelling and bleeding are common, adding further risk. Management brings together much of what has been discussed elsewhere in this book with varying emphases, depending on the injuries suspected or sustained.

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12.1 Initial Considerations

The Advanced Trauma and Life Support (ATLS™) protocol has generally been accepted as the standard approach in managing severely or multiply injured patients. This has been discussed in detail elsewhere, but to remind us the key elements include an appreciation of the mechanism of injury, the need for frequent reassessment and the "ABCDEs" of assessment. Accordingly, in any panfacial injury the airway, breathing and circulation are of immediate concern. Specifically for the facial surgeon, initial concerns focus on the areas discussed below.

12.1.1 Airway

Panfacial injuries are at risk of both immediate or delayed airway obstruction. Immediate airway obstruction may occur from inhalation of tooth fragments, accumulation of blood and secretions, or the loss of tongue support in the unconscious and semiconscious patient. Vomiting can occur unexpectedly. Anaesthetic assistance should be sought early and care taken if intubation is required. In situations where the patient can maintain their own airway, it must be remembered that there is always the potential for obstruction to develop later on, as the tissues begin to swell. Furthermore, as patients tire or become drowsy (from brain injury, alcohol, opiate administration etc.), maintaining a patent airway may become increasingly difficult. In some cases preemptive intubation may be the safest option and this needs to be considered early.

Intubation in the presence of facial trauma is a highly specialised skill. Some important anaesthetic considerations include:

- Risks with nasotracheal intubation (potential for cranial intubation, dural tears or nasal hemorrhage).
- Risks with rapid sequence intubation (failure to intubate or ventilate the patient could result in a total loss of the airway).
- The role of awake fiberoptic intubation, if time allows.
- From our point of view we should be prepared to perform an emergency surgical cricothyroidotomy at a moments notice.

Other considerations relating to the airway arise during the planning of repair of panfacial fractures. These injuries often require wide access to the facial skeleton, together with intermaxillary fixation during surgery. Edentulous spaces may enable oral endotracheal intubation; however, submental intubation or a tracheostomy may be required. The presence of coexisting injuries (notably chest), significant facial swelling and the likely recovery time will also influence the final choice of airway.

12.1.2 Breathing

"Breathing" issues generally fall outside the remit of most facial surgeons and are not discussed in detail here. Nevertheless ventilatory problems may occur following partial obstruction of the lower airway from teeth, dentures, etc. As part of the team, our role is to consider such causes if concerns with breathing and oxygenation arise.

12.1.3 Circulation

Significant blood loss in panfacial injuries can occur from a number of sites.

- Overt blood loss, with haemorrhage externally from the scalp/facial lacerations
- Covert (occult) blood loss, "internally" from tears in the nasal, oropharyngeal mucosa and from midface/mandibular fractures. If the patient has been intubated, these may become more obvious.

External lacerations can usually be managed by direct pressure. It is important to avoid blind clamping in wounds, especially where important structures (such as the facial nerve) may be inadvertently damaged. Unfortunately when the patient is bleeding from the nose or oropharynx it can sometimes be difficult to identify the exact site. Temporary reduction of fractures with packing usually controls most bleeding, but may require the patient to be intubated. Anterior nasal packing can be achieved with a bismuth iodoform paraffin paste (BIPP) gauze, or ribbon gauze impregnated with petroleum jelly (Vaseline). Alternatively nasal sponges (Merocel tampon) can be used. Posterior nasal bleeding, though less common, can be much more profuse and difficult to control. The insertion of a balloon catheter (either Foley catheters or Brighton balloon) combined with anterior nasal packing is often required to control this. Similarly, bleeding from the oropharynx can be difficult to stop. If it is profuse, packing the pharynx with gauze around the endotracheal tube may be the only way to control significant bleeding. In essence, these measures are a form of "damage control"—the aim is to rapidly stop blood loss. In most cases they will be sufficient; however, occasionally interventional radiology or surgical control is required.

> It's important to remember to check the patient's blood pressure before declaring that the measures used to stop bleeding have been successful. The patient may be hypotensive, resulting in temporary haemostasis, only to rebleed once the systemic pressure has been restored.

12.1.4 Disability and E for "Eyes" (and Exposure)

Brain injury and visual impairment are commonly associated with panfacial fractures. One of the main issues is identification of these injuries in the patient who has been intubated early to protect their airway. This is discussed in Chap. 1, initial considerations.

Following resuscitation and stabilisation, consideration of the mechanism of injury helps anticipate what injuries the patient may have. Since panfacial injuries follow significant force, it is likely that nearby structures may also be injured. Detailed and systematic assessment must therefore include the scalp (skull), eyes, ears, nose, teeth, throat and neck (remembering cervical spine protection). Assessment of the remainder of the patient (chest, abdomen, pelvis, spine and limbs) falls out with the remit of this book.

> From our perspective when assessing panfacial injuries, it is important to consider potential damage to the brain, the eyes, and the cervical spine. Missed injuries to these structures will have significant consequences for the patient.

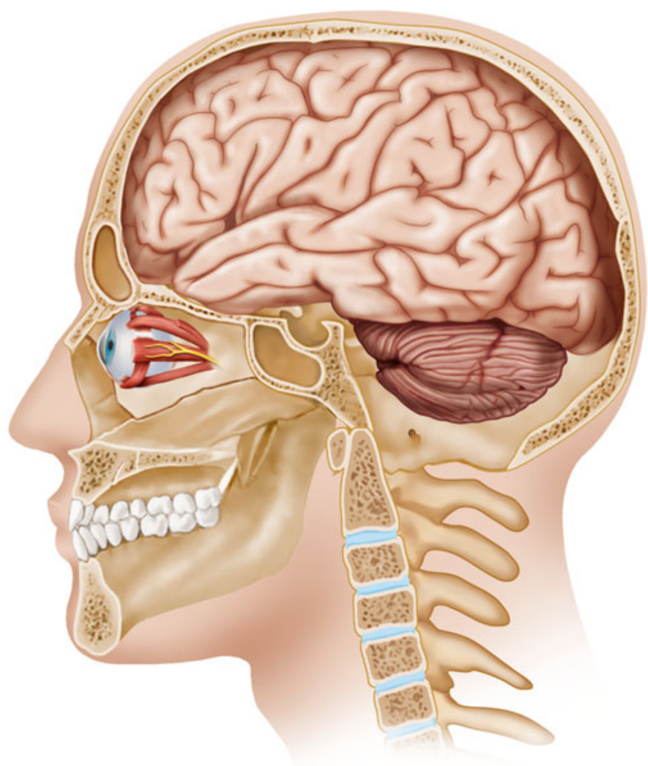


Fig. 12.1 Note the close proximity of the eyes, brain and cervical spine to the midfacial region. Consider injuries above the collar bones as a "package" composed of these three sites in addition to the face

12.2 Applied Anatomy

The facial skeleton is composed of a number of “strut-like” bones which can be thought of as “suspended” from the inclined skull base. These form the boundaries of the orbits, sinuses and nasal cavity. The thicker bones are connected together by thinner “sheets” of bone, to which the soft tissues of the face are attached. Overall, this arrangement provides support and protection to the different functional tissues of the face—notably the facial muscles, eyes, dentition and upper airway. Together with the overlying soft tissue envelope, they define the shape of the face.

The thicker bones can be grouped into four transverse and four (paired) vertical “buttresses” (Table 12.1, Figs. 12.2 and 12.3), and it is the precision in the repair of these bones (in all three dimensions) that is especially important in facial trauma. The transverse buttresses define facial projection and width, while the vertical buttresses define facial height. Consequently when planning surgery it may be useful to consider the fracture pattern in terms of these buttresses. In most cases these will be the sites of internal fixation. Comminution in one or more buttresses is particularly important as bone grafting may be required.

Table 12.1 Anatomy of the buttresses

TRANSVERSE BUTTRESSES
Upper frontal buttress: supraorbital rims and glabellar region
Zygomatic buttress: zygomatic arch, body and lateral orbital wall
Maxillary buttress: maxillary alveolus and hard palate
Mandibular buttress: the basal bone of the mandible extending from the distal mandibular angles, through the body and parasymphysis to the midline
VERTICAL BUTTRESSES
The lateral vertical buttresses. This extends from the molar teeth and lateral maxillary alveolus to the zygomatic process of the frontal bone and laterally to the zygomatic arch. This will include the lateral orbital wall and across the frontozygomatic suture
The medial or nasomaxillary buttresses extends upwards from the cuspid and anterior portion of the maxillary alveolus, along the rim of the pyriform aperture, the medial side of the orbit through the anterior lacrimal crest and nasal process of the maxilla, to the supraorbital rim and the nasofrontal junction to the frontal bone
The paired **posterior maxillary buttresses**. These attach the maxilla posteriorly to the pterygoid plate of the sphenoid bone and from there to the cranial base. This buttress is not easily accessible and therefore not usually repaired
The paired **vertical mandible buttresses** consist of the condyle, ramus and proximal angle

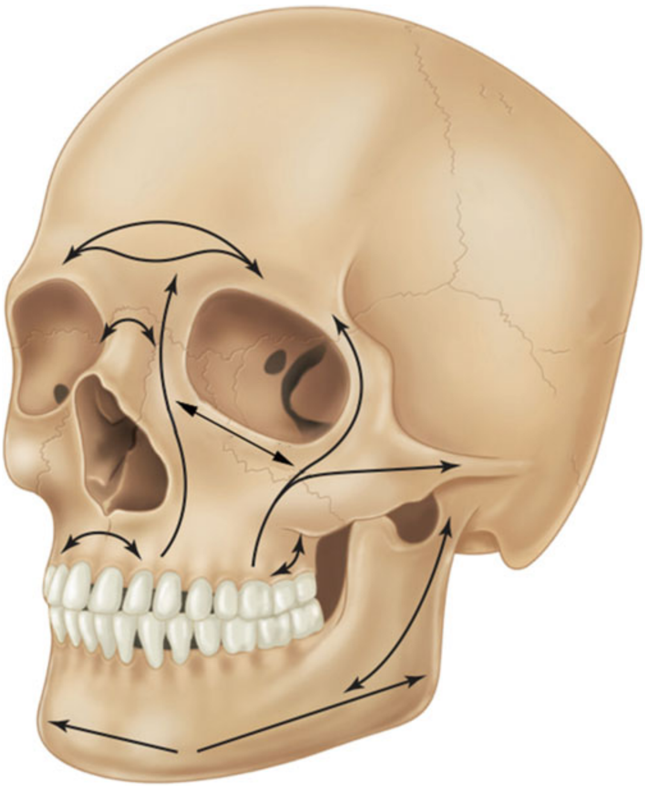


Fig. 12.2 Schematic representation of transverse and vertical buttresses

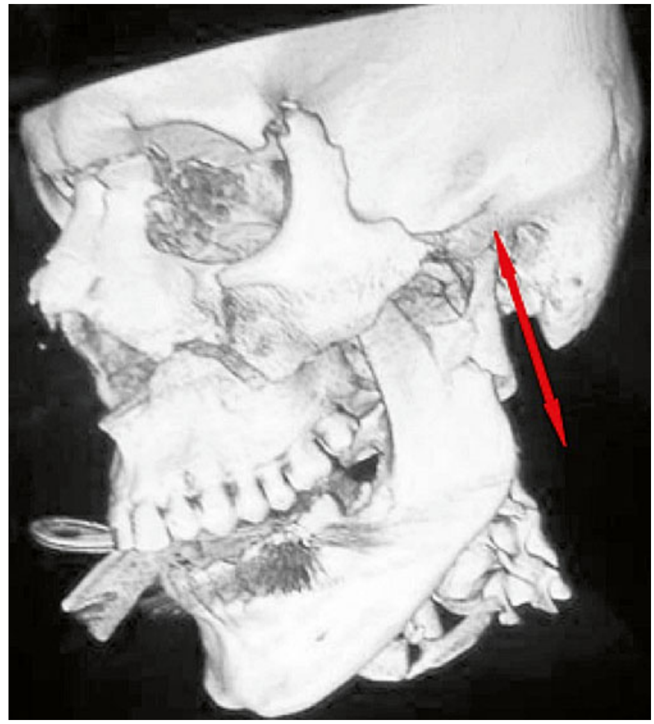


Fig. 12.3 Collapse of the posterior vertical mandibular buttress, with loss of posterior facial height (*double red arrow*), can occur with telescoping or displacement of condylar fractures. This is a key area in assessment

12.3 Specific Considerations in Panfacial Fractures

An important element in management is the accurate assessment and identification of all "key" fractures and any significant associated injuries (Table 12.2). Although all fractures should be identified, some are more important than others, particularly when planning manipulation and internal fixation. This includes sites such as the skull base, nasoethmoid region, orbital apex, palate and condyles.

Although plain radiographs may be of some diagnostic use, all patients should ideally have a CT scan with facility to display fine cut, axial, coronal and sagittal views. Three-dimensional (3D) imaging is also very useful, but caution is advised in relying solely on this. At sites where the bone is thin (notably the orbital walls), 3D images may not accurately reflect the operative findings. Nevertheless, information received from CT scans is very helpful in planning repair. This may include ensuring appropriate equipment available (notably choice of plating kits and "extras"), whether bone grafting is required and the duration of surgery.

Another important element in planning is the occlusion. Dental models are helpful in assessing the configuration of maxillary and mandibular arch fractures. They are also useful in the fabrication of acrylic stents, splints and custom arch bars (for example, to reduce palatal fractures).

Further considerations include how soon surgery should be undertaken. "Early" intervention (approximately 7–10 days) has been advocated and reported to result in improved functional and cosmetic outcomes. Unfortunately, gross swelling or coexisting injuries may preclude this and longer delays may be unavoidable. In situations where treatment is delayed for more than 3 weeks, repair becomes technically much more difficult.

Table 12.2 Specific areas to focus on when assessing panfacial fractures

Clinically
Inspect the nasal bridge for widening, telecanthus or asymmetry (nasoethmoidal injury)
Look for CSF leakage (is this a craniofacial fracture?)
Assess vision and ocular motility
Inspect the globe for malposition: proptosis, enophthalmos, vertical dystopia
Are there any midpalatal splits?
Examine occlusion for open bites as a result of condylar injuries
Are there any displaced mandibular fractures?
Radiographically (**CT**)
Frontal sinus/skull base
Orbital apex/orbital walls
NOE region
Zygomatic arches
Palatal splits
Condylar neck/head
Sites of comminution
The presence of simultaneous displaced fractures to both dental arches (neither arch can then be used as a reference for the other). Increased transverse facial width can occur if this is overlooked

12.4 Surgical Access and Sequencing

Adequate exposure of panfacial fractures is essential for precise repair. If required, the entire face can be accessed by carefully placed incisions. Those which are commonly used are summarised in Table 12.3. When exposure of the orbital regions is required, some surgeons advise that periorbital/eyelid incisions should be placed prior to raising a coronal flap or degloving the midface. This allows the placement of aesthetic incisions before swelling obscures eyelid anatomy.

One of the main principles in panfacial fracture repair is to accurately restore the facial buttresses in all three dimensions. However, the precise order in which the fractures are repaired has been much debated. Sequencing is now much less critical than previously. This is because the development of rigid fixation now means that midface repair can precede fixation of the mandible, provided the buttresses can be precisely aligned.

Currently there is still no consensus as to which is the best sequence. “Bottom to top”, “top to bottom”, and “outside to inside” are just a few sequences that have been proposed, based on the importance of various fracture sites such as the zygomatic arch, or dental occlusion. In practice these sequences do not always follow a simple order and there is some degree of overlap between them—for example, the bottom-to-top approach begins with the mandible and occlusion, then moves to the cranium and frontal bones, before moving down to the midface. Similarly, the top-to-bottom approach begins at the cranium, working down to the mandible before returning to the orbits and nasoethmoidal region. The order of reduction is therefore not as sequential as the names imply. However, this is not a criticism of these approaches, but it does serve to emphasise the complexity in planning and repairing these cases. Due to the varying permutations of fracture patterns possible in panfacial fractures, no single sequence will reliably work every time. Don’t be afraid to be flexible in your sequencing. Try to think logically about what the next step should be and its effects on the whole, rather than blindly following a formula.

Some of the sequences commonly reported are as follows.

Table 12.3 Access to the face

Common incisions[a]	Structures exposed
Coronal	Frontal, nasoethmoidal, upper three quarters of orbit, nasal root, zygomatic arch, skull
Upper lid	Frontozygomatic suture, lateral orbital rim and wall
Transconjunctival/subciliary / subtarsal/mid lid	Inferior orbital rim, orbital floor, lower medial/lateral orbital walls
Maxillary gingivobuccal sulcus	Maxilla, midfacial buttress
Mandibular vestibular	Mandibular symphysis to sigmoid notch
Preauricular, retromandibular	Mandibular condyle, ascending ramus, lower border posterior mandible
Existing lacerations	Direct access

[a]This is not an exhaustive list. Other incisions exist

12.4.1 Bottom to Top (Inside to Outside)

The first step is to reestablish the “maxillomandibular unit” (MMU). This requires at least one intact dental arch. If both arches are disrupted they need to be repaired first. Once the correct width of one dental arch is restored, this can be used as a reference for the other.

Mandibular fractures should ideally be repaired completely, including the condyles. Anatomical reduction and fixation of the transverse mandibular buttresses (body, parasymphysis/symphysis) restores lower facial width. Anatomical reduction of the vertical mandibular buttresses (condyles) will restore the posterior mandibular height and chin position. However, in some cases, repair of the condyle may be technically difficult. In these cases intermaxillary fixation will be required postoperatively.

Palatal fractures can be either repaired anatomically to establish the preinjury maxillary arch width, or reduced and supported by custom made splints, following preoperative dental impressions and model surgery.

Following restoration of the MMU, the sequence then continues, starting at the calvarium and proceeding in a caudal direction. The forehead is repaired (paying attention to the correct management of the frontal sinus), followed by the nasoethmoid complex. This is followed by further repair of the “outer facial frame” beginning at the root of the zygomatic arch and advancing to the lateral orbital walls and infraorbital rims. The final correction is at maxillary buttress, nasal complex/septum and orbits.

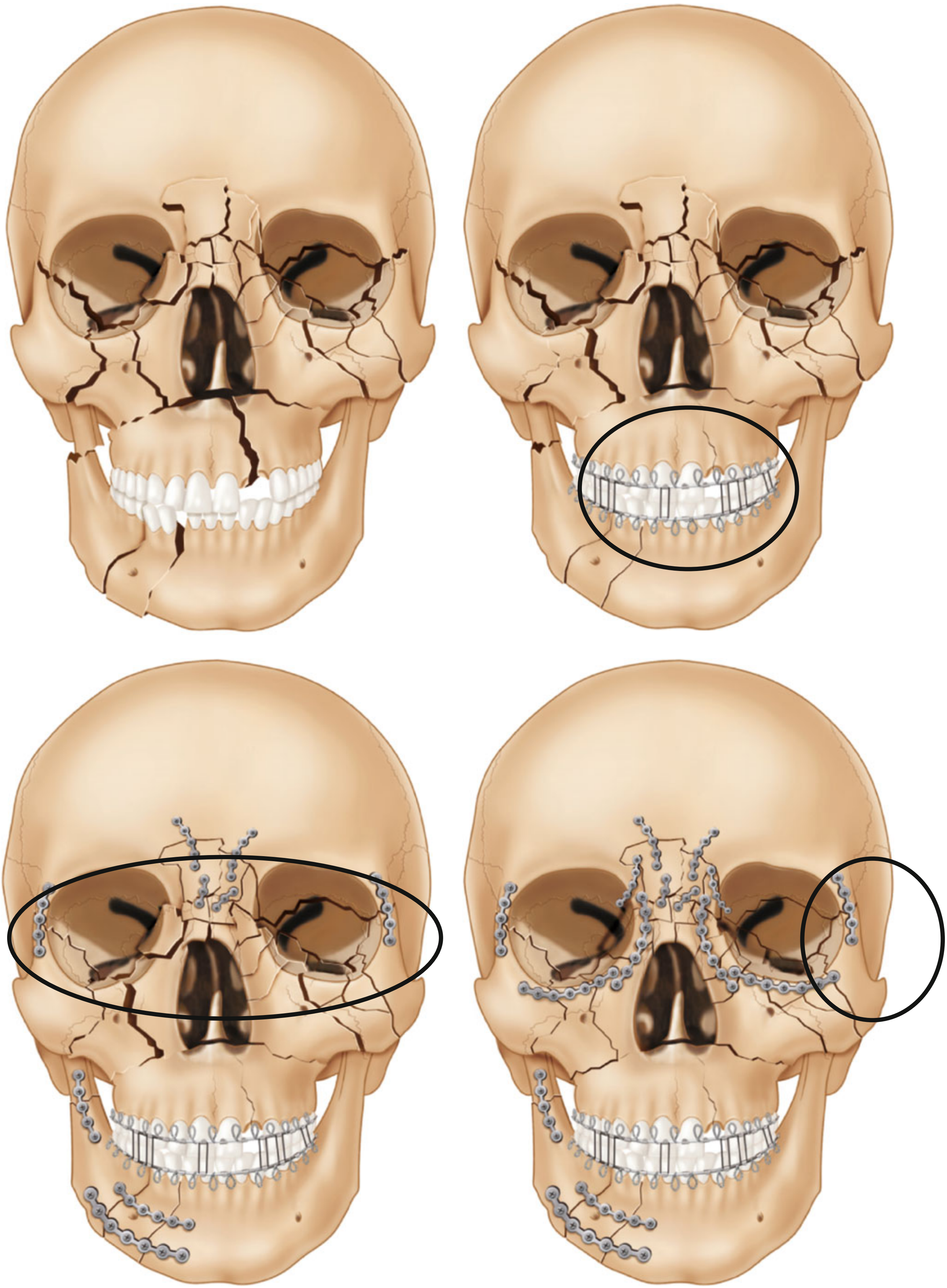


Fig. 12.4 Bottom to top sequence (see text for details). The *black circles* simply indicate the areas of interest when thinking about strategic planning

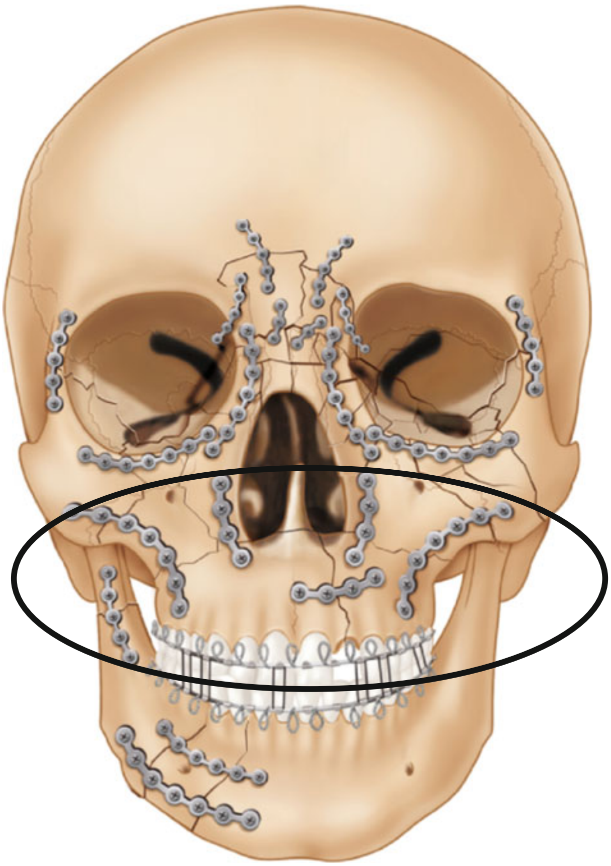


Fig. 12.4 (continued)

12.4.2 Top to Bottom

Commencing at the forehead, calvarial, frontal sinus and orbital roof fractures are repaired first. The zygomas are then repositioned, using the lateral wall of the orbit with the greater wing of the sphenoid as a guide. The zygomatic arches and infraorbital rims are then aligned, followed by repair of the nasoethmoid and nasal bones (in cases where the medial canthal tendon requires repair, this is left as the final step, before soft tissue closure). Midface reconstruction around the medial and lateral buttresses is then undertaken, followed by maxillomandibular fixation and repair of any mandibular fractures, including the condyles. The final fractures to be repaired are the orbital walls and floor.

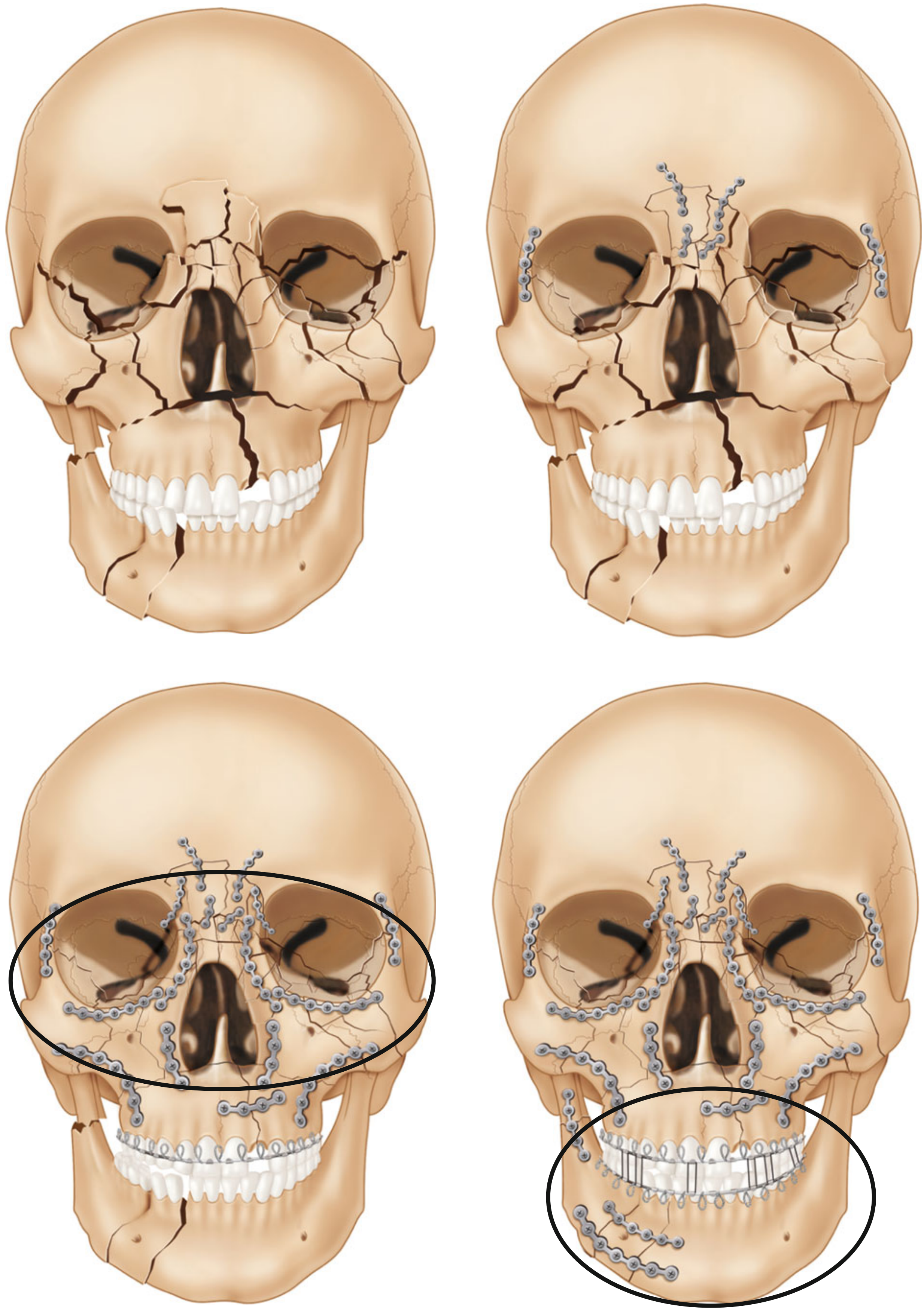


Fig. 12.5 Top to bottom sequence (see text for details). The *black circles* simply indicate the areas of interest when thinking about strategic planning

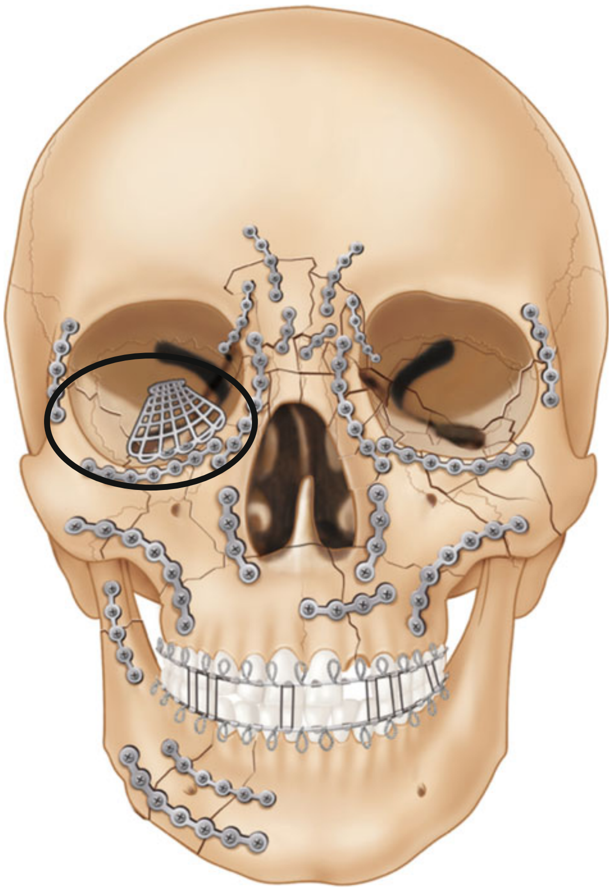


Fig. 12.5 (continued)

12.4.3 Outside to Inside

This approach commences along the "outer facial frame," beginning at the root of the zygomatic arches and advancing along both malar complexes to the frontal bone. Early repair of the frontozygomatic sutures restablishes facial height. The frontal bar is also repaired at this stage. This is followed by repair of the "inner facial frame" (the nasoorbitoethmoid complex), thereby establishing the correct anteroposterior projection and transverse width of the upper face. Intermaxillary fixation is then placed to establish the occlusion, lower facial projection and width. The maxillary buttresses, symphyseal/parasymphyseal fractures and condylar fractures can then be repaired. In this approach fractures of the condyle can be treated closed. It can be seen that this approach has many similarities to the top to bottom sequence.

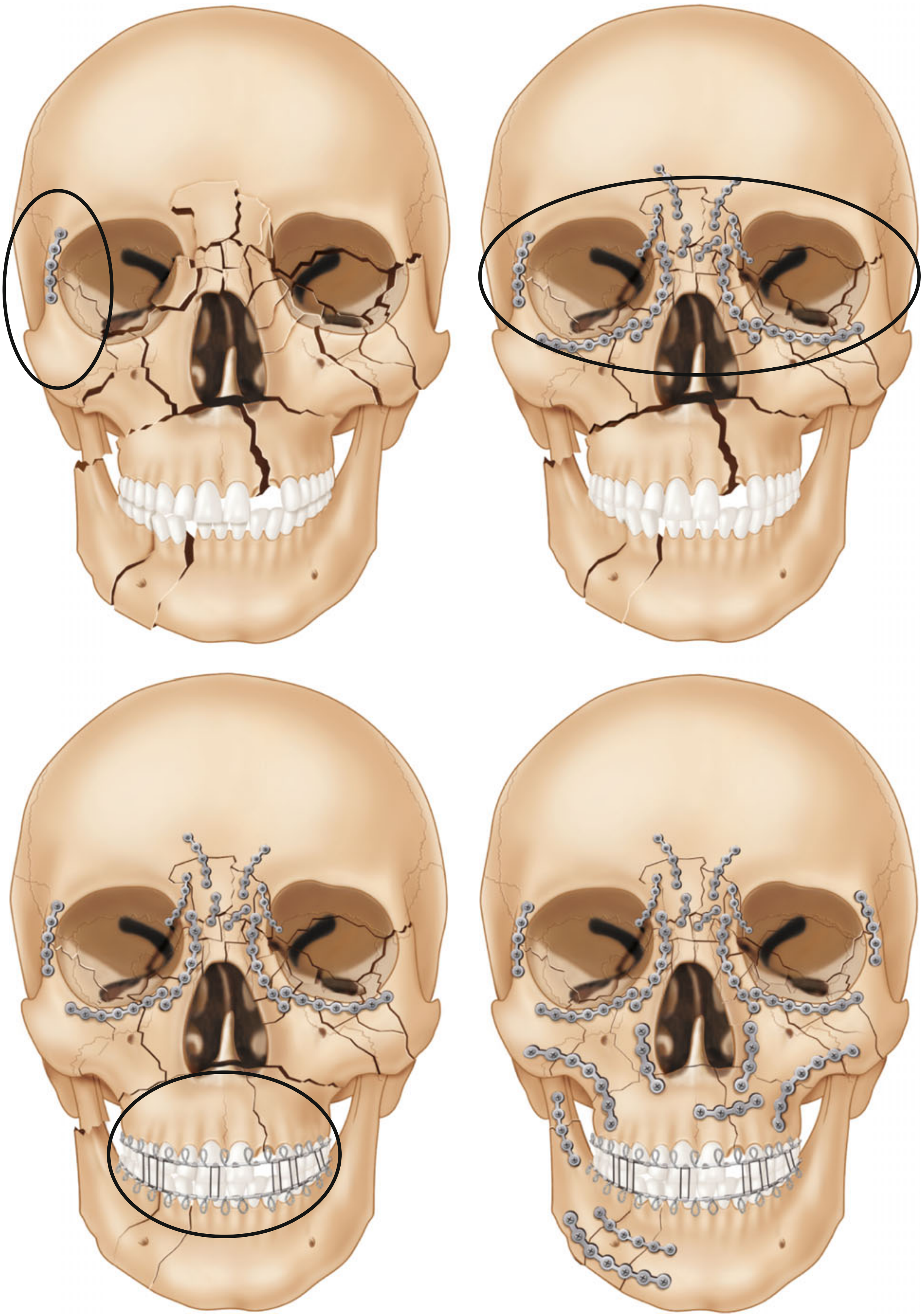


Fig. 12.6 Outside-in sequence (see text for details)

Not surprisingly, in view of the varying complexity of fractures patterns, some degree of flexibility may be required. So long as certain key points are considered, rigid adherence to one or other of these approaches is probably not that critical. Some useful points are noted in Tables 12.4 and 12.5.

Table 12.4 Some useful tips in repair

If necessary expose all the fractures
Begin with anatomical reduction of the larger fragments, working from stable, nonfractured bone towards the more displaced regions
As you progress throughout the operation, reassess all your previous fixation sites—these can become displaced as you manipulate other bones
Precise anatomical reduction may not be possible with every fracture and minor irregularities are common. By themselves, each irregularity may not be significant, but multiple ones can collectively add up, resulting in an overall poor repair
Precise repair of the frontal bone, lateral wall of the zygoma and zygomatic arch requires an intact cranial base. These are used to establish the anteroposterior, and transverse dimensions of the face. Pay particular attention to these
Other important components of central facial width are the NOE complex, the palate and the mandibular arch
Remember the adverse effects on the transverse facial width when both dental arches are fractured
Overall facial width is established by the frontal bar, zygomatic arches, malar eminences and mandibular angles. Accuracy of repair at these sites must be critically assessed
The condyles are important in establishing facial height
Zygomatic arches can bow rather than break—but they still need to be aligned
Don't forget the nasal septum
Meticulous periosteal suspension and soft tissue repair, are as essential to a good outcome as the bony reduction

Table 12.5 Important elements in three-dimensional repair

Central midface Dental arches Palate Nasoethmoid (transverse width of the orbits)
Facial height Midfacial buttresses Condylar height (posterior facial height) Nasofrontal bone repair and septum (anterior projection of the nose)
Facial width Root of zygomatic arch (anterior projection and transverse width of face) Lateral orbital wall alignment (transverse width and height of zygomatic complex) Frontal bar Mandibular angles
Orbital floor (vertical and anterior position of globe)
Precise soft tissue repair and resuspension

12.5 Case Examples

The following cases are shown to highlight some of the approaches used to sequencing and to explain why a particular sequence was followed in each case. This is not to say that these are to be regarded as the "definitive" sequence, others are just as valid. Rather they are used to highlight some of the thought processes involved in treatment planning.

Case 1

- Patient was the victim of an assault.
- ATLS protocol intubated in accident and emergency with oral endotracheal tube.
- Transferred to intensive care unit.
- Traumatic optic neuropathy right eye; did not recover.
- No neurological concerns
- Preoperative CT imaging
- Discussion with intensive care staff; patient was awakened and full neurological assessment undertaken. No spinal or brain injury.

Fractures Sustained

- Right mandibular angle
- Bilateral zygomas
- Comminuted midface (Le Fort 1 and bilateral nasomaxillary)
- Nasal/septal fractures
- Large defect right orbital floor

Alternative "Buttress-Based" Assessment

- Transverse buttresses
  - Upper frontal—intact supraorbital and glabella region
  - Zygomatic buttress fractures—right zygomatic arch, infraorbital rim and orbital floor displacement, left infraorbital rim and zygomatic arch and orbital floor displacement
  - Maxillary buttress—intact alveolus and hard palate
  - Mandibular buttress—right mandible angle fracture displacement with resultant dysocclusion
- Vertical buttresses
  - Lateral vertical buttress—left and right lateral buttress fracture. Gross displacement left frontozygomatic (FZ) suture and lateral wall
  - Medial Buttress—fracture of right pyriform rim. Nasoethmoid wall intact. Left pyriform rim fractured but minimally displaced.
  - Nasal bridge fractures
- Posterior maxillary buttress—displaced
- Vertical mandible buttresses—condyles and ramus intact

Favourable Aspects

- Large fragments with relatively little comminution at each fracture site.

Unfavourable Aspects

- Widespread fractures with no solid facial foundations to use for initial reference
- Need for IMF and free access to the nasal cavity.
- Already poor prognosis to one globe—significant implications of any iatrogenic injury to the other globe (care with repair)

Surgery

- Percutaneous tracheostomy

Access via

- Coronal flap
- Bilateral transconjunctival incisions
- Upper vestibular
- Intraoral and transcutaneous to lower right mandibular border

Sequencing and Rationale

Due to the large, easily reducible fragments, the mandibular angle was repaired first. Since the fracture did not span the lower dental arch, IMF was not required for this. However, it was essential to repair this as accurately as possible. Therefore a transcutaneous approach was used to facilitate accurate assessment of the entire fracture and placement of an additional lower border plate.

Following this, arch bars were placed and intermaxillary fixation (IMF) was applied. The coronal flap was raised and attention turned to the bilateral zygomatic fractures. FZ plates were placed to establish their correct vertical positions. The correct projection and transverse position of the right zygoma was confirmed using anatomic alignment of the right arch, together with alignment of the intact right nasoorbital bones and infraorbital rim. On the left side the arch was in an acceptable position and therefore not plated. Correct 3D orientation of both zygomas was verified by inspecting (and then plating) the lateral orbital walls.

With the patient in IMF, the maxillary buttresses were repaired (by using the repositioned mandible and zygomas as reference points to aid reduction). This aided restoration of the transverse facial width (beware palatal splits).

Attention was then turned to the remainder of the central midface (bilateral nasomaxillary fractures). The right side and left sides were aligned using the pyriform aperture and infraorbital rims in relation to the repositioned zygomas and maxilla. The left nasoorbital segment was sprung laterally and carried the medial canthal attachment, so secure fixation was essential to minimise late drift. The coronal flap allowed exposure of the superior aspect of this fragment and anatomical repair. The fracture was also plated at the infraorbital rim.

Finally the orbital floors were explored. The right required repair. The left did not. The case was finished with manipulation of the nasal bones and placement of septal splints and packs, prior to closure.

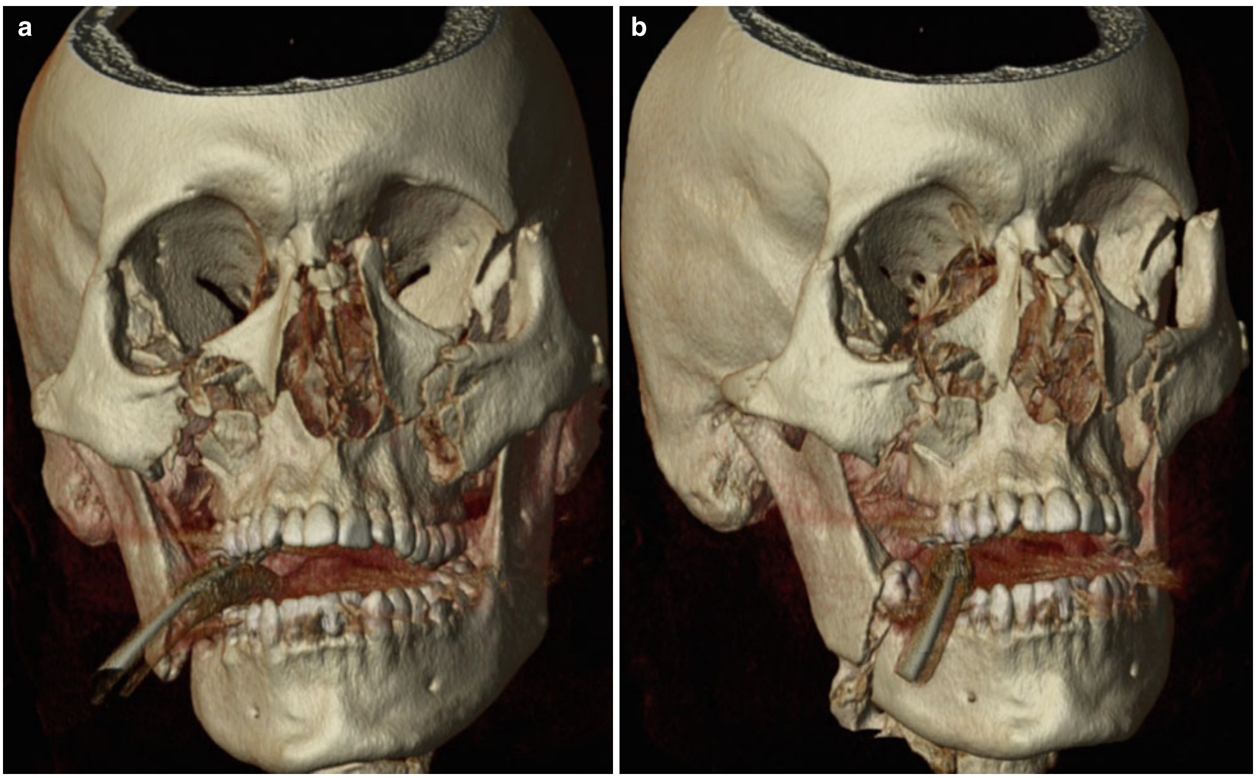


Fig. 12.7 Case 1 sequence (**a**–**e**)

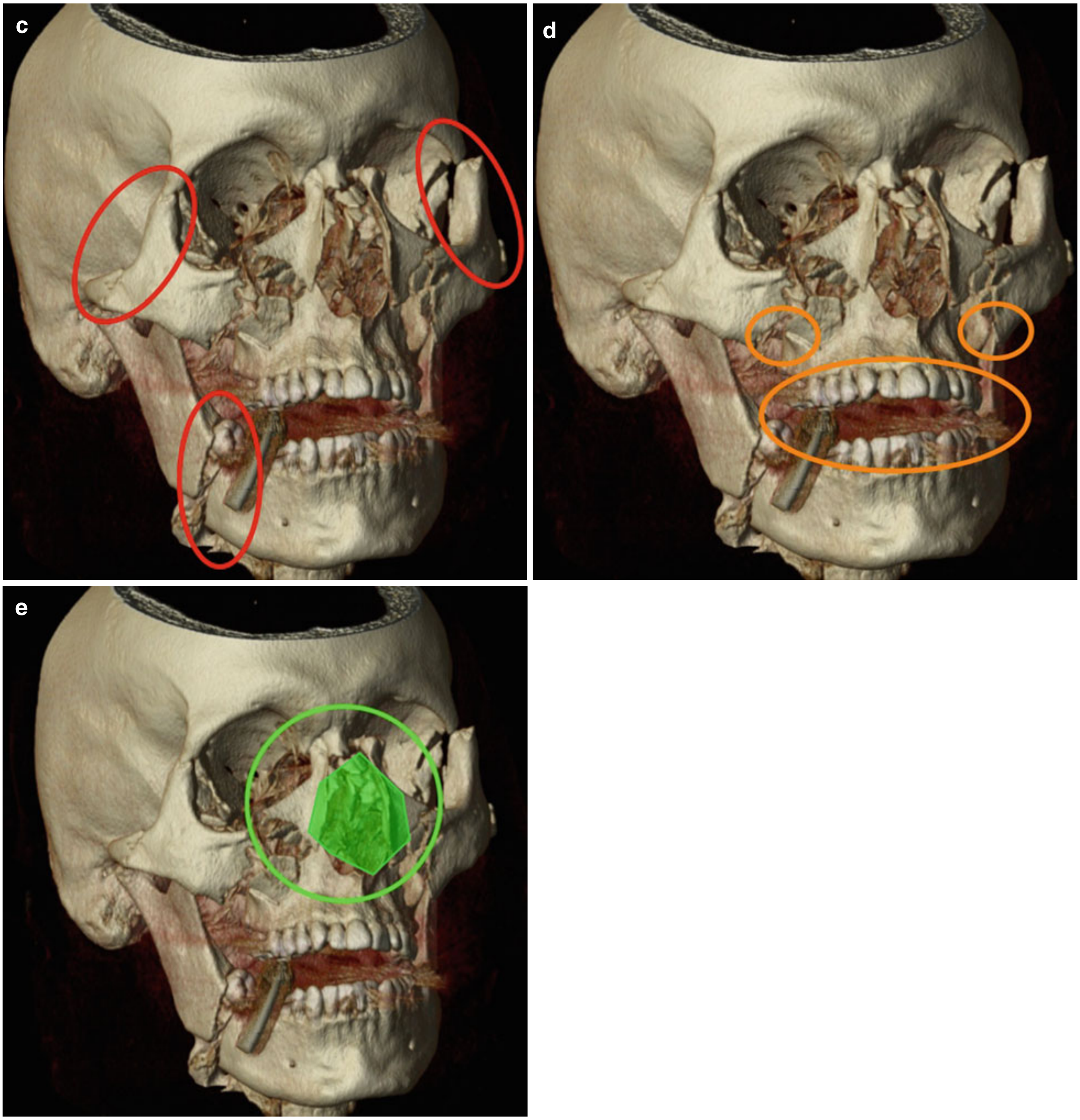


Fig. 12.7 (continued)

Fig. 12.8 Case 1 postoperative result (**a**, **b**)

Case 2

- Patient was the victim of an assault with baseball bat.
- ATLS protocol. Airway secure, no major bleeding. Bridle wires placed.
- No neurological concerns.
- Preoperative CT imaging.

Fractures Sustained

- Bilateral mandibular fractures
- Left zygoma
- Comminuted left nasomaxillary and nasal fractures with unilateral naso-orbitoethmoid (NOE) fracture
- Anterior wall frontal sinus

Alternative "Buttress-Based" Assessment

- Transverse buttresses
  - Upper frontal—intact supraorbital rim, but depressed fracture nasal bridge / glabella region
  - Zygomatic buttress—right zygomatic arch, infraorbital rim and orbital floor intact.
  - Left infraorbital rim and zygomatic arch displacement, orbital floor minimally displaced.
- Maxillary buttress—intact alveolus and hard palate
- Mandibular buttress—right and left parasympyhseal fractures with displacement and resultant dysocclusion
- Vertical buttresses
  - Lateral vertical buttresses—right lateral buttress intact, displaced left lateral buttress maxilla. Displacement of left FZ suture and lateral orbital wall displacement.
- Medial buttresses—fracture right pyriform rim, lateral nasal bone displacement. Left pyriform rim fracture with nasoethmoid displacement.
- Posterior maxillary buttress—undisplaced.
- Vertical mandible buttresses—condyles and ramus intact

Favourable Aspects

- Large mandibular fragments with relatively little comminution at each fracture site
- Intact right maxilla and upper dental arch to facilitate mandibular reduction.
- Intact right zygoma

Unfavourable Aspects

- Comminution around left NOE region
- Telescoping of left zygomatic arch
- Need for IMF and free access to the nasal cavity.

Surgery

- Percutaneous tracheostomy

Access via

- Coronal flap
- Left transconjunctival incision
- Upper left buccal sulcus
- Intraoral mandibular

Sequencing and Rationale

Due to the large, easily reducible fragments and intact dental arch, the mandible was repaired first. Hand-held IMF only was required.

Following this, attention was turned to the left zygoma. Access to the arch, FZ and NOE region was gained via a coronal flap. FZ plates were placed to establish the correct vertical height and the arch aligned and plated to establish cheek projection. A left buttress plate was placed, using the undisplaced left hemimaxilla as a reference. This restored the transverse facial width. Correct 3D orientation of the bones was verified by inspecting the lateral orbital wall.

Attention was then turned to the nasomaxillary fractures, frontal sinus and bridge of nose. The anterior wall of the sinus was removed to inspect the posterior wall and frontonasal patency (both were intact). The fractures were repaired commencing with the uppermost fractures. The infraorbital rim was then fixed (providing further support to the transverse facial width). Additional support to the comminuted NOE region was provided using a canthal wire.

Finally the orbital floors were explored. Neither required repair. The case was finished with manipulation of the nasal bones and placement of septal splints and packs, prior to closure.

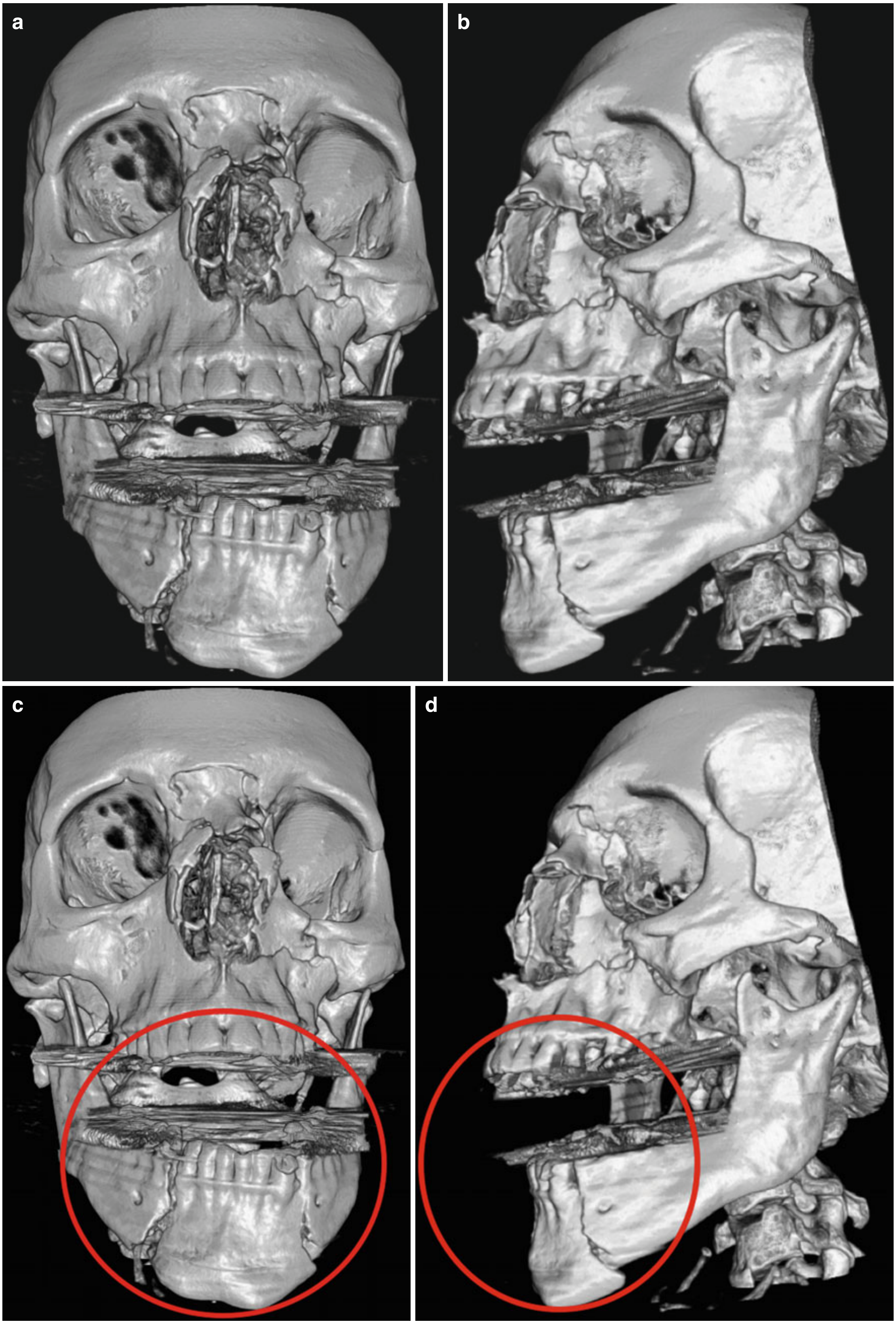


Fig. 12.9 Case 2 sequence (**a**–**h**)

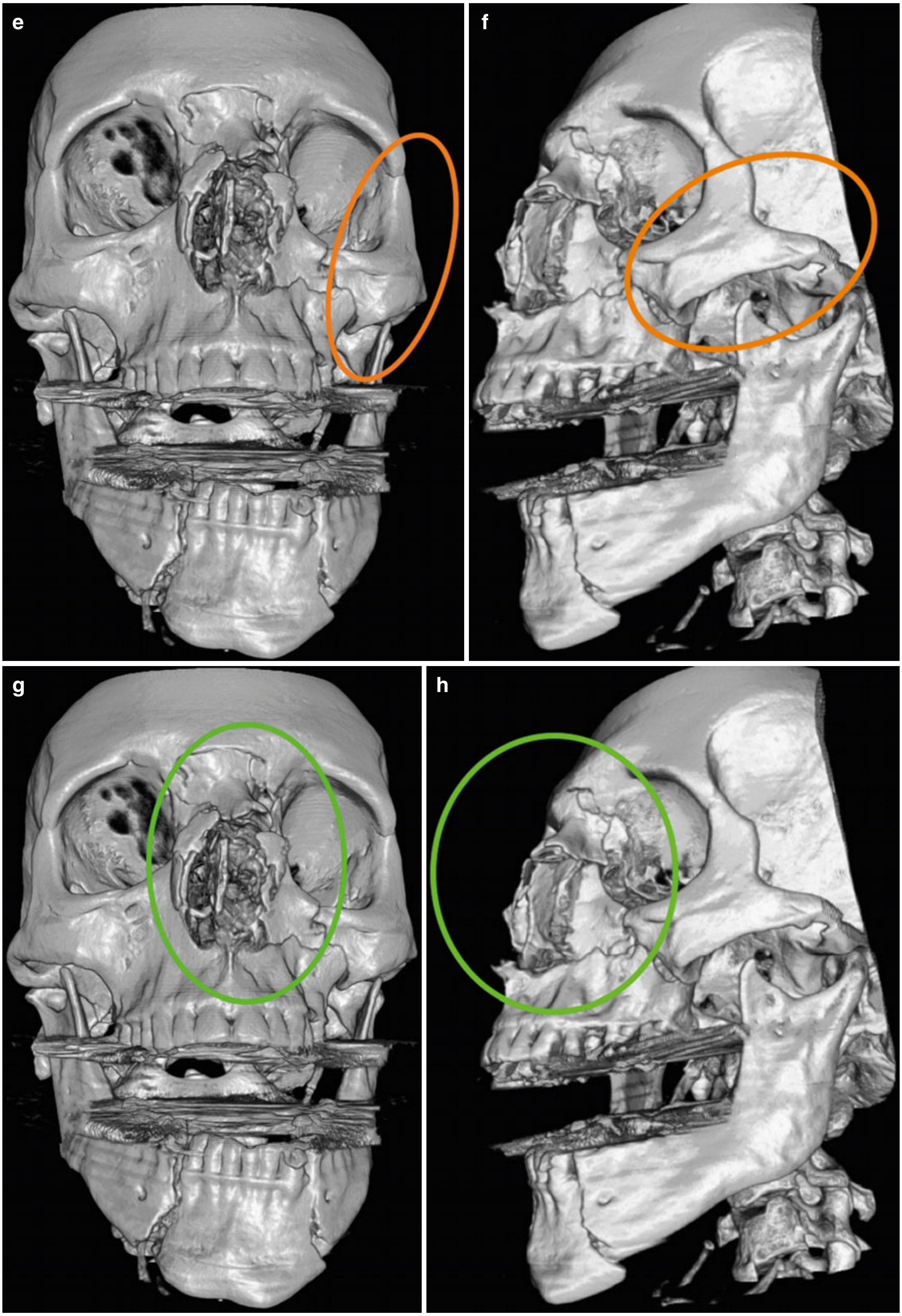


Fig. 12.9 (continued)

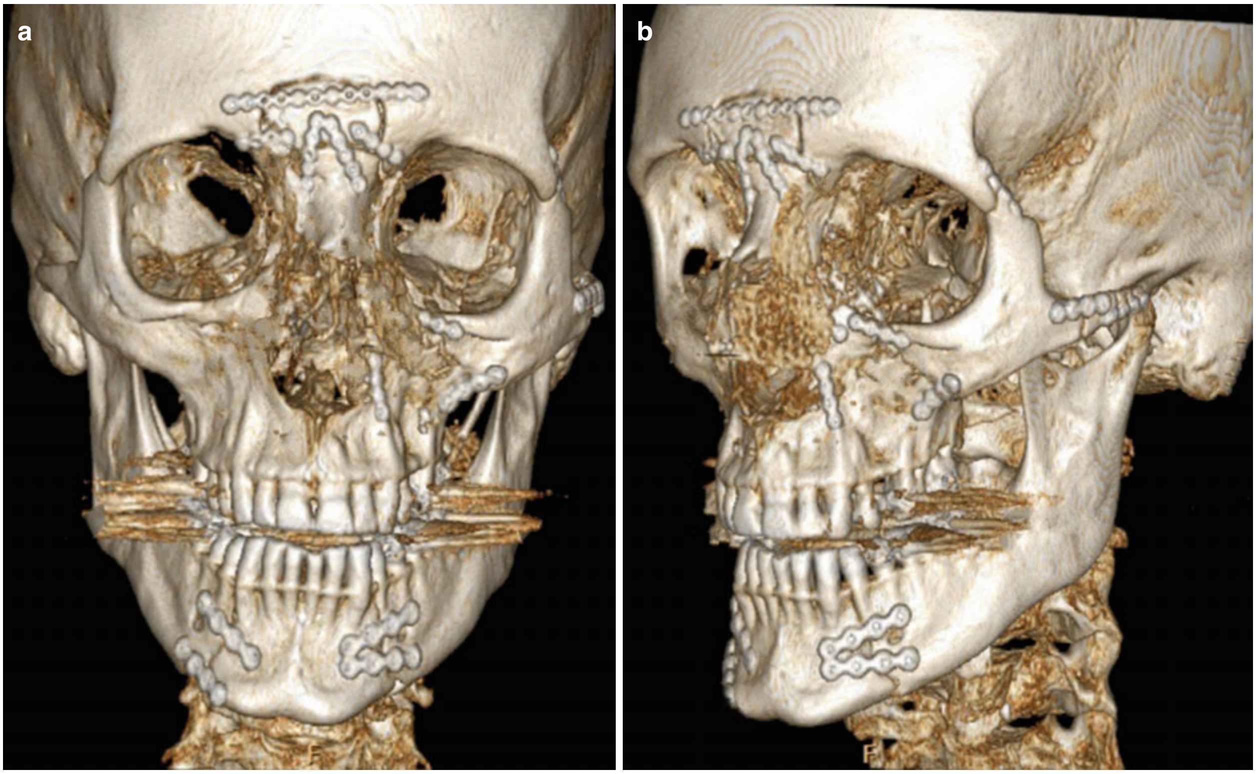


Fig. 12.10 Case 2 postoperative result (**a**, **b**)

Case 3

Patient fell approximately 25 ft, while attempting to climb a drainpipe! He landed on "all fours" sustaining bilateral wrist and lower limb injuries, followed by an impact to the face.

- ATLS protocol—intubated in Accident and emergency with oral endotracheal tube. Significant bleeding requiring nasal packing for 48 h. Transferred to intensive care unit.
- Preoperative CT imaging
- Discussion with intensive care staff. Patient was awakened and full neurological assessment undertaken. No spinal or brain injury. Discussion with neurosurgeons: no intervention required regarding ACF fractures.

Fractures Sustained

- Right mandibular parasymphysis and high left condyle
- Right zygoma
- Moderately comminuted midface
- Anterior wall frontal sinus/ACF
- "En block" impacted fracture of bridge of nose/bilateral nasomaxillary fractures, with NOE fractures.
- Nasal/septal fractures
- Large defect right orbital floor
- Loss of upper anterior teeth/multiple cusp fractures

Alternative "Buttress-Based" Assessment

Transverse buttresses

- Upper frontal—frontal bone fractures involving right and left supraorbital rims. Depressed fracture nasal bridge/glabella region
- Zygomatic buttresses—fractures of right zygomatic arch and infraorbital rim. Displaced orbital floor. Left infraorbital rim displacement. Left zygomatic arch and orbital floor minimally displaced.
- Maxillary buttress—widened maxillary alveolus midpalate split
- Mandibular buttress—displaced right parasymphyseal fracture with resultant dysocclusion

Vertical buttresses

- Lateral vertical buttresses—right lateral buttress displaced. Right FZ suture undisplaced. Displaced fracture lateral orbital wall.
- Left lateral buttress maxilla displaced. Undisplaced left FZ suture and lateral wall.

Medial buttress—right and left pyriform rim fractures. Nasoethmoid splayed open from impaction of nasal bridge.

Posterior maxillary buttress—displaced

Vertical mandible buttresses—high condylar fracture right side

Favourable Aspects

- Some large fragments with relatively little comminution at each fracture site
- Intact left zygoma

Unfavourable Aspects

- High right condylar fracture with unilateral loss posterior facial height. This was considered too high and too comminuted for repair.
- Difficulty in establishing good IMF due to loss of sound teeth.
- Almost 1 cm impaction of nasal bridge with involvement of ACF (no cerebrospinal fluid [CSF] leak)
- Multiple injuries and their impact on timing of repair.

Surgery

- Oral intubation (due to loss of teeth)

Access via

- Coronal flap
- Bilateral transconjunctival incisions
- Upper vestibular
- Intraoral and transcutaneous to lower mandibular border (via laceration)

Sequencing and Rationale

This commenced with reduction and internal fixation of the midline palatal split. Due to the large, easily reducible fragments, the mandibular was then repaired. Arch bars were placed and IMF was applied. IMF was established with some difficulty due to the loss of teeth. Advantage was taken of the overlying laceration to facilitate accurate repair of the entire symphyseal fracture. This was essential due to the difficulties in establishing IMF. Access enabled placement of an additional lower border plate and critical assessment of reduction.

Following this the coronal flap was raised and attention turned to the right zygomatic fracture. An FZ plate was placed to establish the correct height and the arch plated to establish cheek projection. Correct 3D orientation of the bones was verified by inspecting (and then plating) the lateral orbital wall. With the patient still in IMF, the maxillary buttresses were repaired (by using the mandible and repositioned zygoma as reference points to aid reduction). This restored the transverse facial width.

Attention was then turned to the impacted nasal bridge and bilateral nasomaxillary fractures. The fractured anterior frontal sinus wall was removed to allow direct inspection of the sinus floor. The posterior wall was confirmed to be intact (also no fractures were seen on the scans) so there was no indication to cranialise the sinus. The nasal bridge was disimpacted, watching closely for CSF leakage. The nasofrontal ducts were identified and verified as patent. The frontal wall and nasal bridge fractures were then repaired, followed by the left infraorbital rim. Nasofrontal stents were not required.

Finally the orbital floors were explored. The right required repair. The left did not. The case was finished with manipulation of the nasal bones and placement of septal splints and packs, prior to closure.

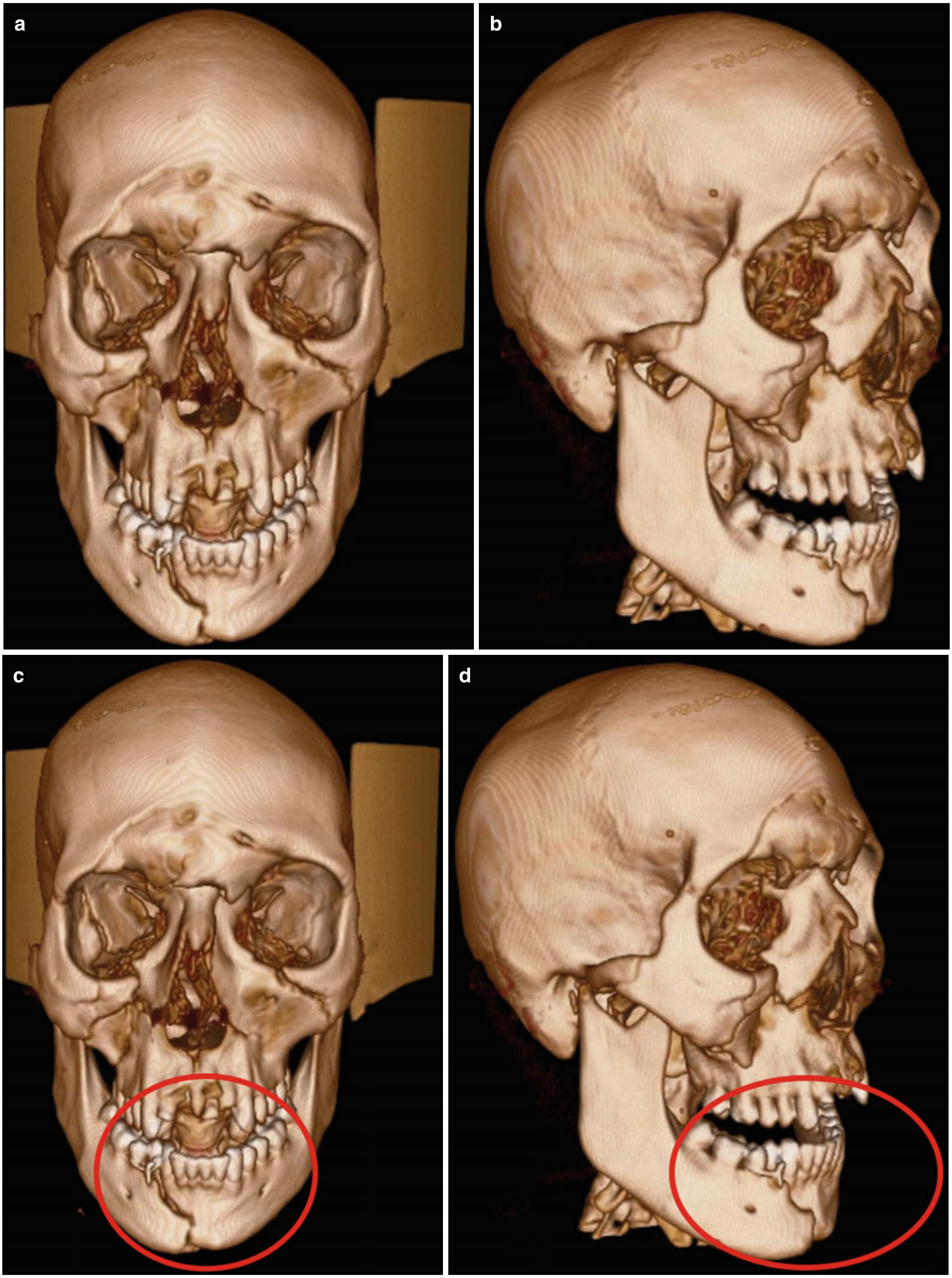


Fig. 12.11 Case 3 sequence (**a**–**h**)

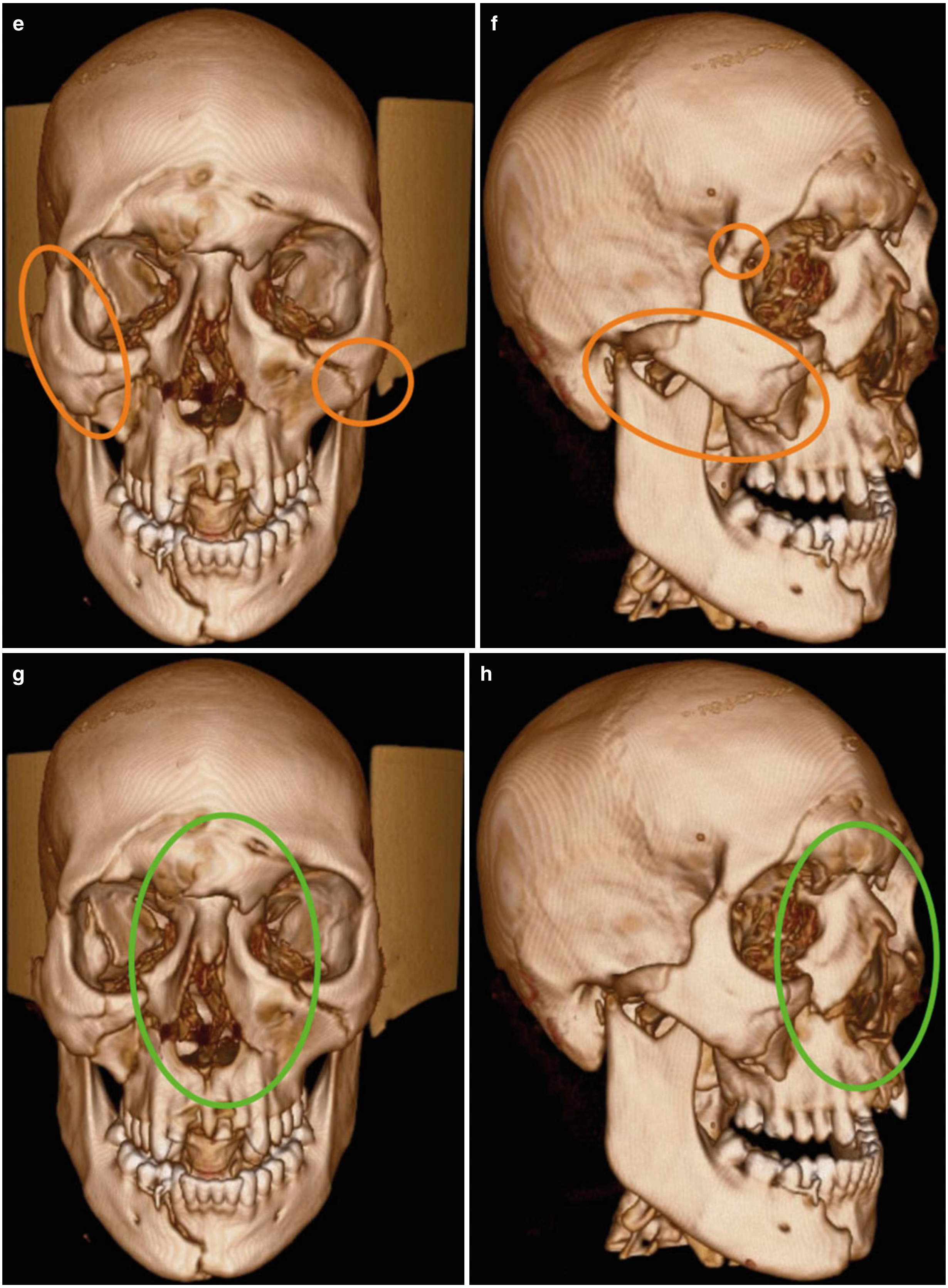


Fig. 12.11 (continued)

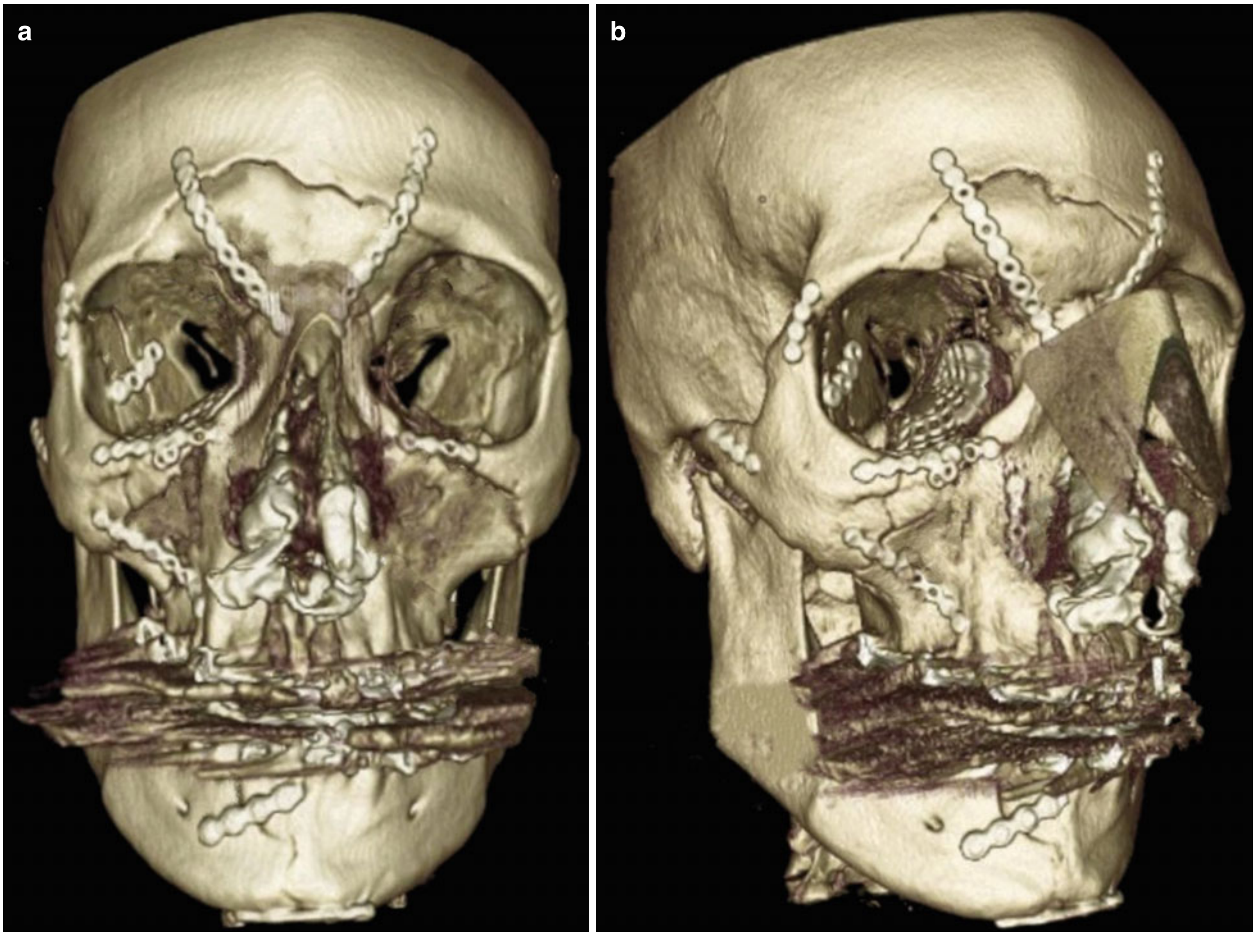


Fig. 12.12 Case 3 postoperative result (**a**, **b**)

Case 4

Patient fell off a ladder approximately 20 ft onto concrete, remaining conscious throughout. ATLS protocol with spinal immobilisation was undertaken. There were obvious forehead and facial injuries, but no major bleeding.

Assessment of his facial injuries quickly followed the primary survey. Although the face was swollen it was considered that the airway did not require urgent intubation. The airway was sufficiently patent and patient was not in distress. The mobile fractures of mandible and maxilla were stabilised with bridal wires. Imaging to the head, torso, spine and wrists was undertaken, in keeping with clinical or suspected injuries.

General Injuries Sustained

- Fracture of the inferior portion of the body of C3 (“tear drop”)—no associated neurological deficit.
- Fracture of the left distal radius—no vascular or neurology signs
- Minor head injury (GCS 14)
- “Panfacial” fractures with involvement of anterior cranial fossa (pneumocephalus)

The patient was initially admitted for head injury observation. Following discussion with neurosurgery, a conservative approach to the pneumocephalus was advised, with planned rescanning to ensure resolution. Orthopedic opinion: conservative management of C3 fracture using an Aspen collar. However, significant neck movement was to be avoided for at least 4 weeks. Rescan if develops neurological symptoms or signs. Fractured left distal radius was put in a back slab for subsequent fixation.

Facial Fractures Sustained

Both the anterior and posterior walls of the frontal sinus and ACF were fractured (with minimal displacement of the posterior wall). There was a small amount of pneumocephalous and two small subdural contusions, but no detectable CSF leak. Other injuries included:

- “En block” impacted fracture of bridge of nose with bilateral nasomaxillary fractures and NOE fractures.
- Nasal/septal fractures
- Moderately comminuted midface. The maxilla was split resulting in a large left dentoalveolar fracture. Fractures to medial and lateral walls of the maxilla completed a “high” Le Fort–type fracture.
- Bilateral zygomas with a large defect in the right orbital floor
- Fractured mandibular parasymphysis and bilateral condyles. Right condyle was significantly displaced and overlapping.
- Loss of upper anterior teeth/multiple cusp fractures

The overall effect of these injuries was to widen the transverse dimensions of the face while reducing the anterior–posterior length.

Alternative “Buttress-Based” Assessment

- Transverse Buttresses
  - Upper frontal—frontal bone anterior and posterior walls and supraorbital rims bilaterally. Depressed fracture of the nasal bridge/glabella region
  - Zygomatic Buttress—increase facial width due to bowed zygomatic arches.
  - Displacement of right infraorbital rim, left infraorbital rim and right orbital floor.
- Maxillary Buttress—widened maxillary alveolus and mid palate split resulting in a large left dentoalveolar fracture
- Mandibular buttress—right parasymphyseal fracture displacement
- Vertical Buttresses
  - Lateral vertical buttress—right lateral buttress displaced. Right FZ suture displaced with fracture of the lateral wall. Left lateral buttress of the maxilla displaced. Left FZ suture and lateral wall displacement.
  - Medial buttress—right pyriform rim fractures. Left pyriform rim and nasoorbital fractures comminuted. No canthal widening
- Posterior maxillary buttress—displaced
- Vertical mandible buttresses—left and right condylar fractures, telescoped on the right

Favourable Aspects

- Bowing of zygomatic arches meant these did not require exposure.
- Not all sites were comminuted. Some fractures were simple.
- No CSF leakage.

Unfavourable Aspects

- Bilateral condyle fractures with loss of posterior facial height.
- Difficulty in establishing effective IMF due to dentoalveolar fracture and dental injuries.
- Cervical spine injury meant patient required fixation of skull to operating table using Mayfield clamp. The head could not be turned or extended to improve access.

Surgery

Following resolution of the facial swelling and pneumocephalus, the patient was taken to theatre for joint orthopedic and panfacial repair. The patient’s neck was stabilised during induction of anaesthesia using a collar,

sandbags and tape. Initial awake oral intubation was performed using a fiberoptic scope. A Mayfield clamp was then placed to stabilise the neck. Postoperative swelling was anticipated, together with the need for heavy postoperative IMF, so a percutaneous tracheostomy was performed.

Access via

- Transparotid approach to both condyles
- Transcutaneous to lower mandibular border
- Coronal flap with pericranial flap
- Transconjunctival incisions
- Upper vestibular incision

Sequencing and Rationale

Following fixation with the Mayfield clamp and tracheostomy, the condyle fractures were exposed and repaired. This was necessary to establish posterior facial height and width. Reduction and fixation of the parasymphysis fracture was undertaken using a submental approach to achieve anatomic alignment of the lower border and correct arch width. (Any widening of the lingual aspect would be transferred to the dental arch and ultimately the facial width). These repairs were somewhat difficult since the neck could not be turned or extended. Arch bars were placed at the same time. Ideally the palatal split would have been plated. However, inability to extend the neck prevented adequate access and so the bars were used to support the left dentoalveolar fracture. The maxilla was noted to have been displaced posteriorly and laterally to the right, rotating about the soft palatal tissues.

Following this, the coronal flap was raised and attention turned to the right zygomatic fracture. An FZ plate was placed to establish the correct height, along with examination of the lateral wall of the orbit to ensure anatomic alignment. A lateral orbital wall plate was placed to maintain good alignment.

The left FZ fracture was found to be comminuted and therefore reduced and held in place with a wire. This was initially placed as temporary fixation to allow minor rotation at the suture—precise anatomical reduction was uncertain at that stage due to the comminution at the suture. The lateral orbital wall was then reduced. The zygomatic arches were not exposed. These were bowed, not fractured, and it was hoped that repositioning of the fractured zygomas, together with manipulation of the arches would lead to acceptable alignment. The right maxillary buttresses was then exposed and repaired. The presence of the left dentoalveolar segment (buttress) meant that accurate reduction relied partly on the arch bars establishing the dental occlusion. Fixation here was carried out last as this was the least reliable reduction.

The fractured anterior frontal sinus wall was removed to allow direct inspection of the posterior sinus wall and floor. Although there was comminution of both the posterior wall and floor, the fragments were minimally displaced and there was no CSF leakage. Following disimpaction of the nasal bridge (approximately 6–8 mm) adequate patency of the frontonasal duct could not be determined with certainty. A decision was therefore taken to remove the sinus mucosa and obturate the sinus using bone and pedicled pericranial flap. A small fenestration within the upper fracture line was created for this. The lower ends of the nasomaxillary fractures were then repaired.

The orbital rims were then exposed and the orbital floor explored. The right side was largely intact and therefore left untreated, the left side was significantly fractured and a preformed titanium plate was placed. The left and right infraorbital rims were plated.

The case was finished with manipulation of the nasal bones and placement of septal splints and packs. Soft tissue closure and frontal resuspension.

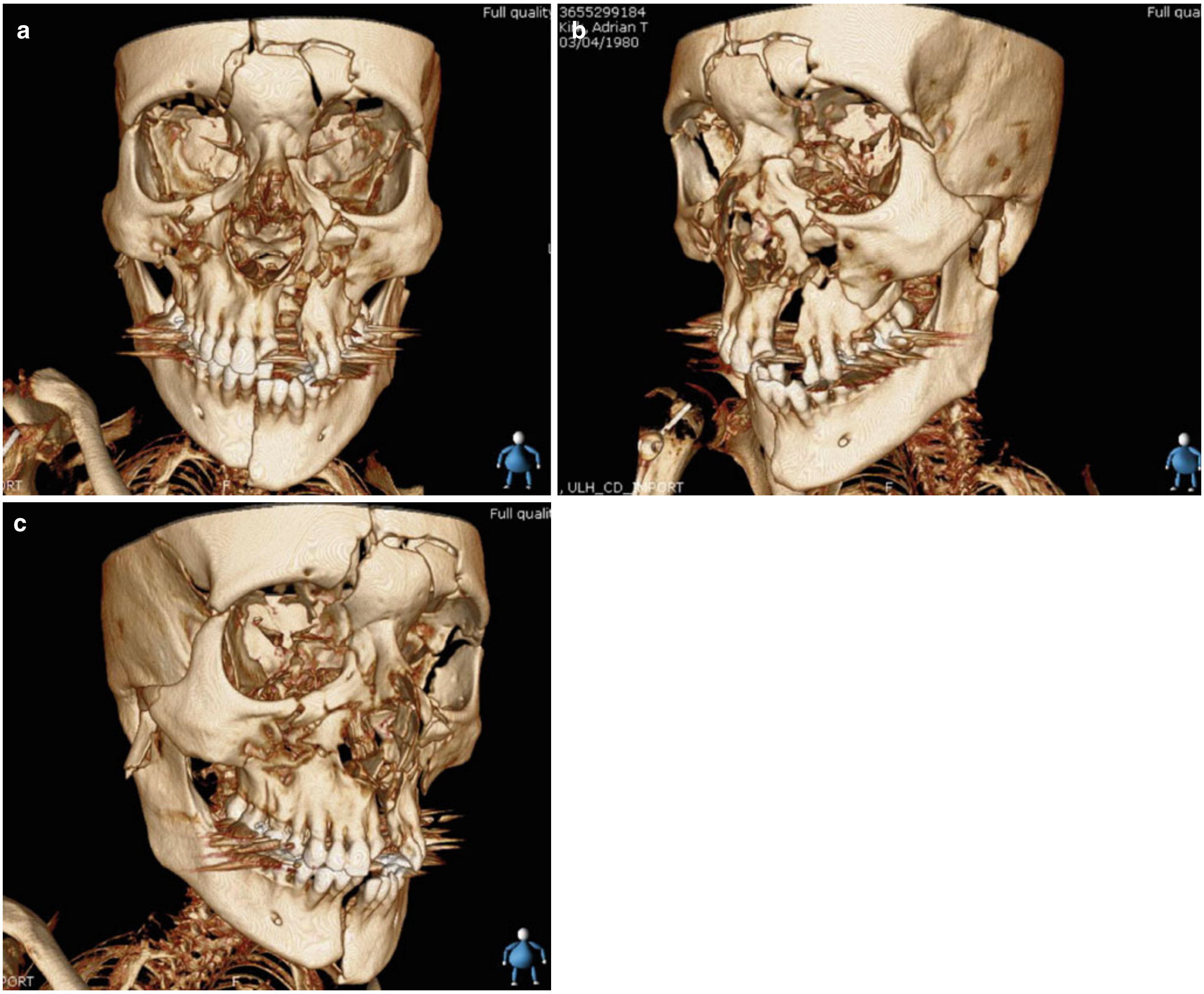


Fig. 12.13 Case 4 sequence (**a**–**l**)

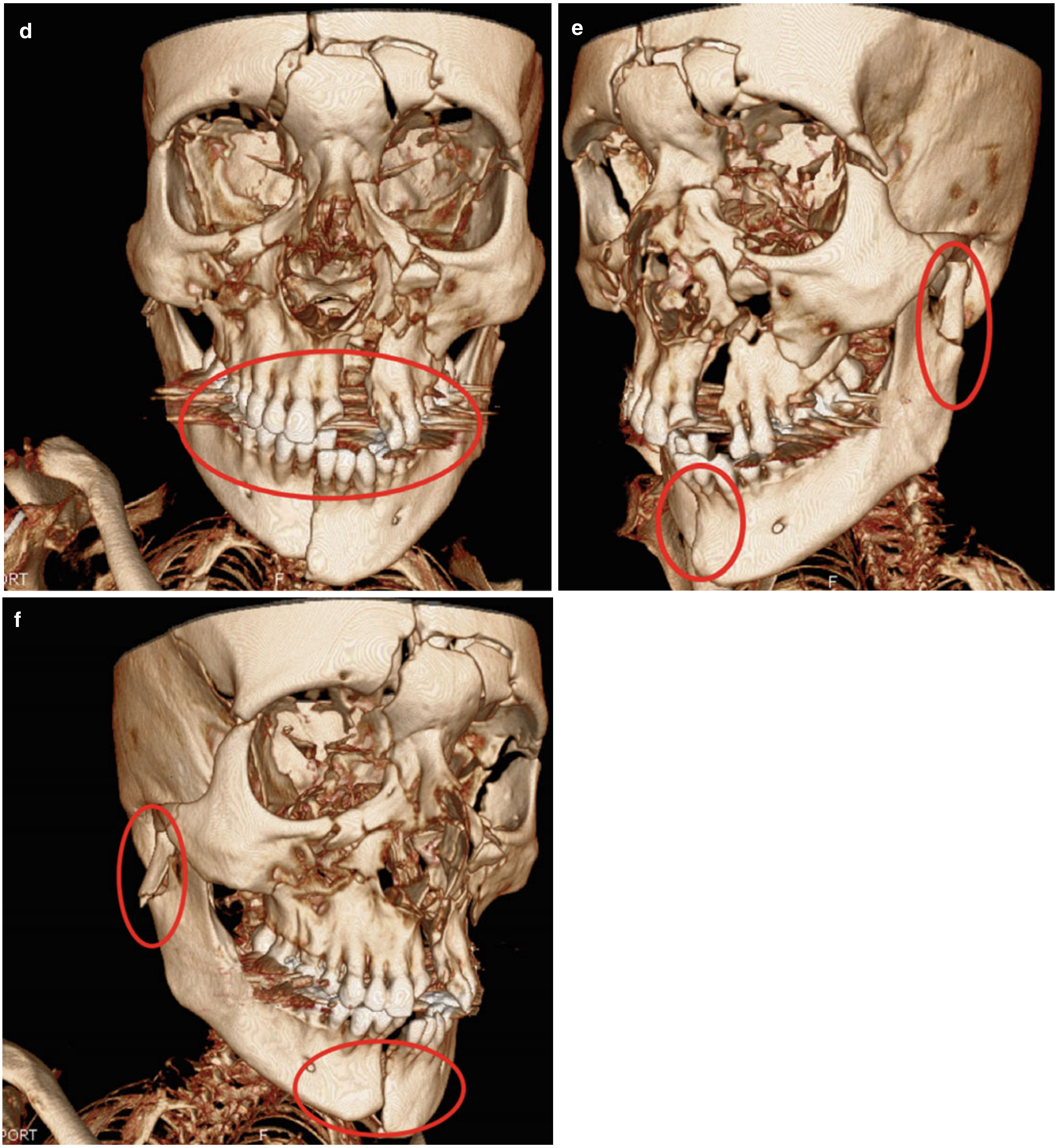
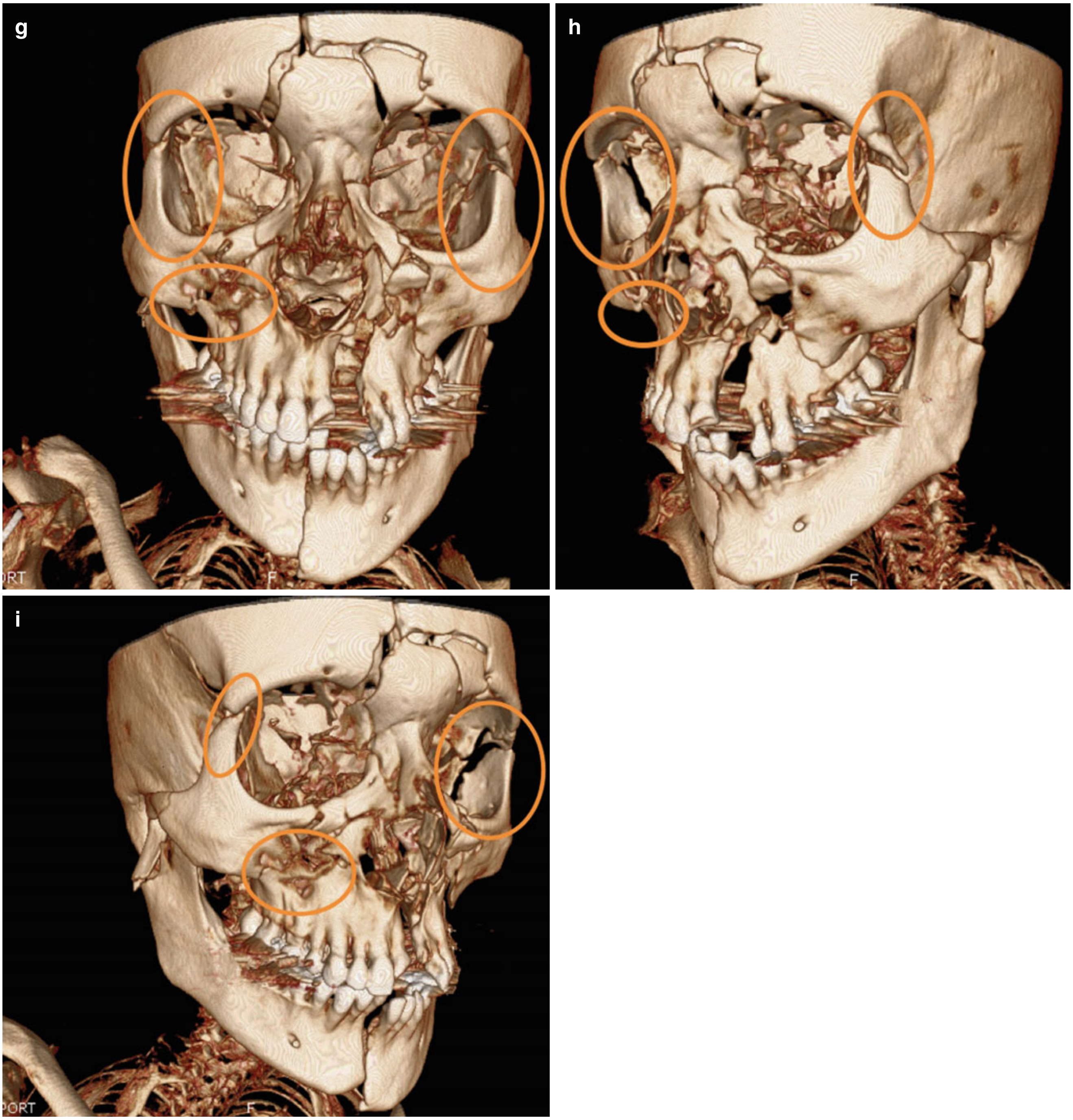


Fig. 12.13 (continued)



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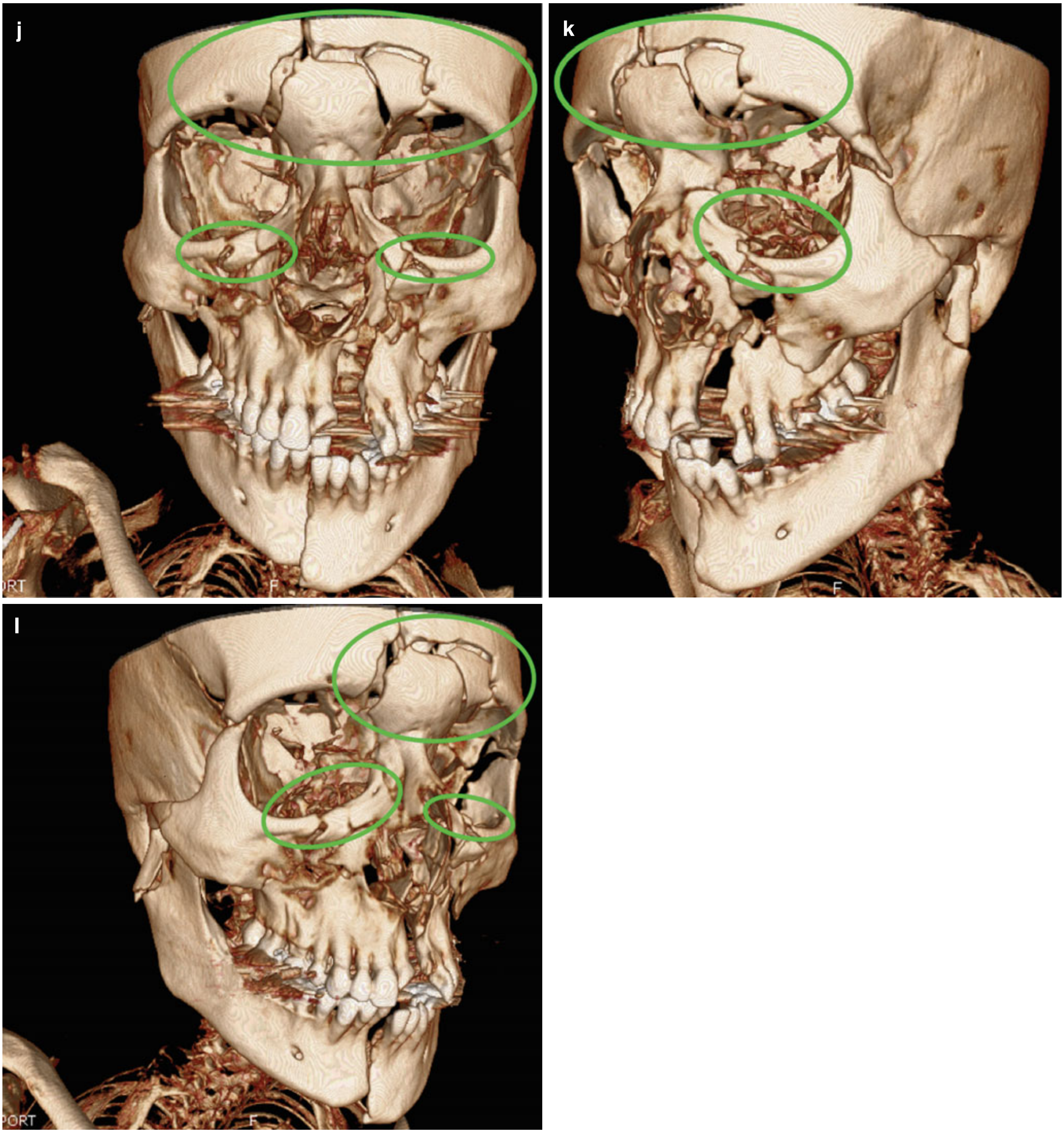

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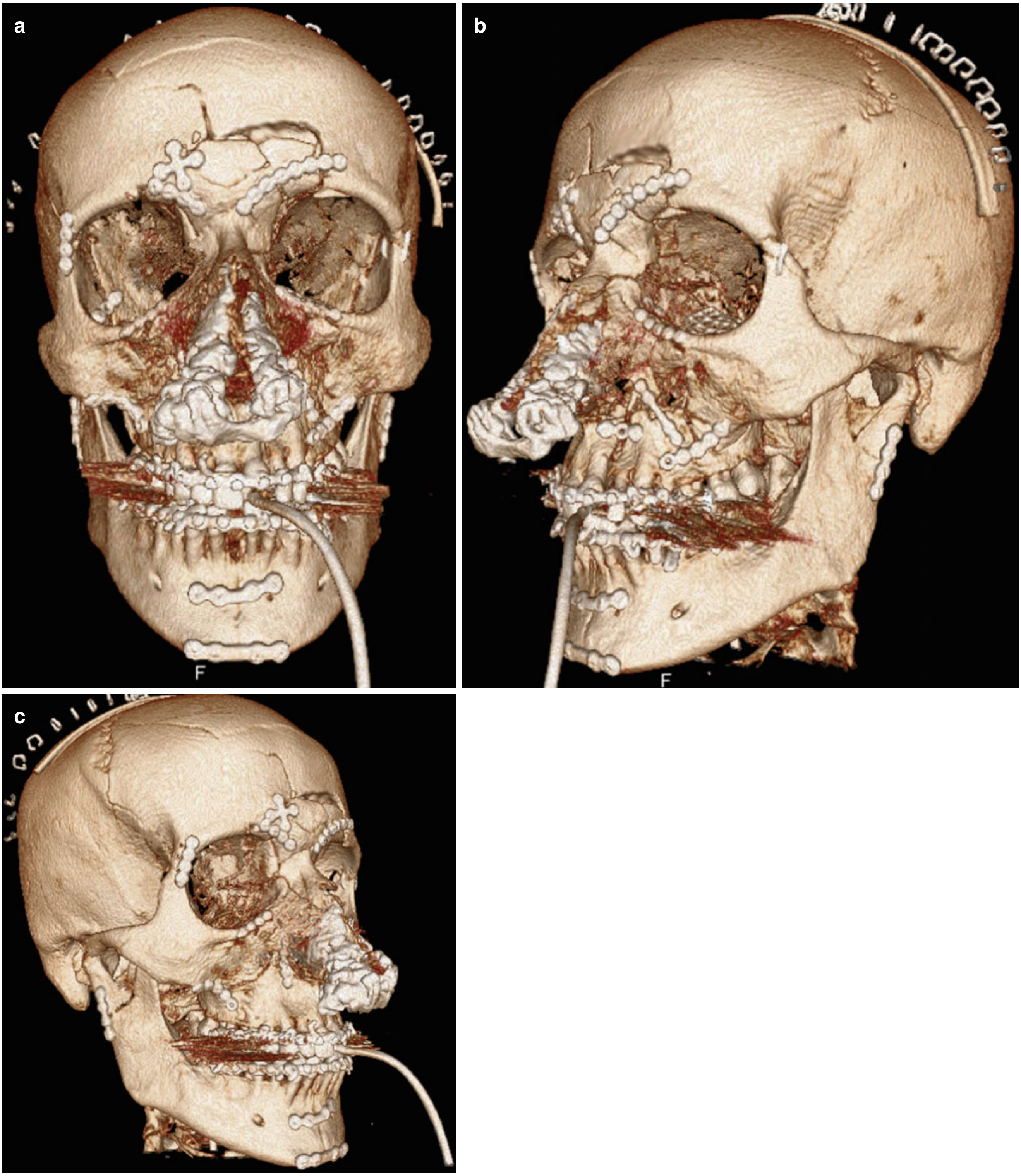

Fig. 12.14 Case 4 postoperative result (**a**–**f**)

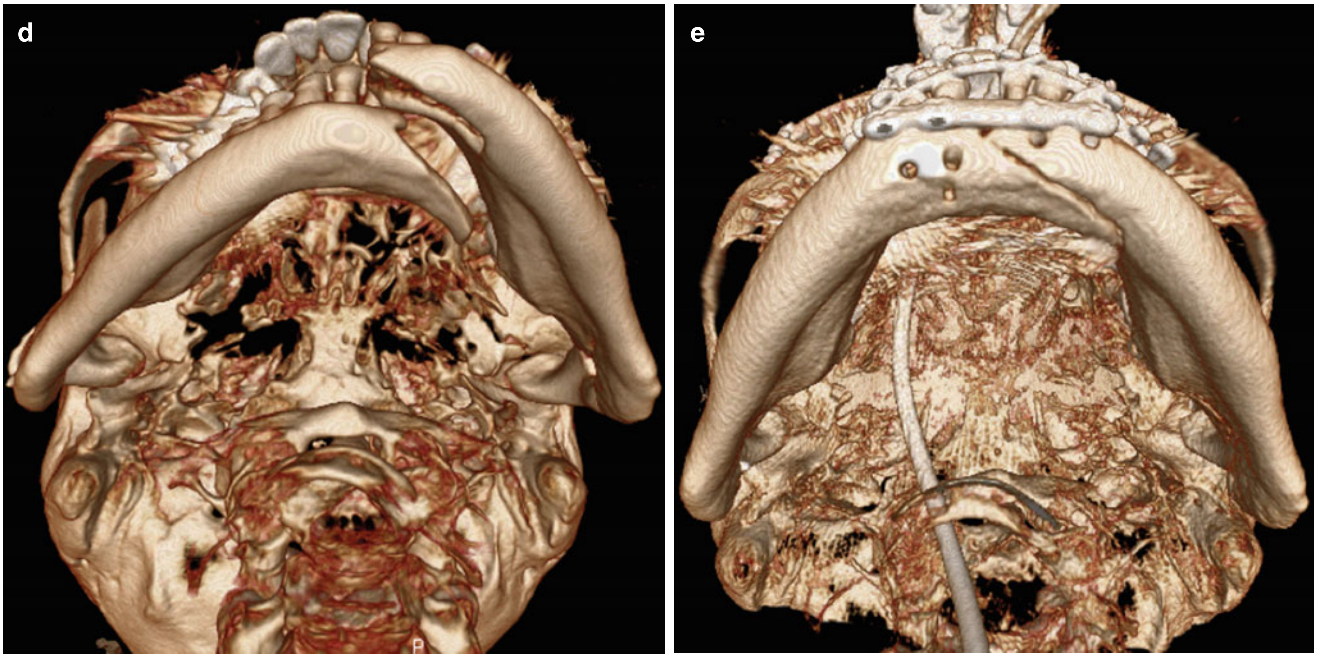

Fig. 12.14 (continued)

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The Coronal Flap

13

Michael Perry and Simon Holmes

The coronal (or popularly missnamed bicoronal) flap is a commonly used flap which provides excellent exposure of the upper half of the face and skull. A number of minor modifications have been described, but the basic concepts and flap design remain the same. By raising the flap in the subgaleal plane, taking with it at least the outermost layer of the temporalis fascia at the sides (several layers have been described), the upper branches of the facial nerve should remain protected and undamaged.

In essence this is a scalping-type procedure in which the front half of the scalp is pulled forwards, pivoting just in front of the ears. Considerable variation in the placement of the scalp incision is possible, allowing a more posterior position in patients with receding hairlines.

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13.1 Applied Anatomy

Anatomists describe the S.C.A.L.P as having five layers: Skin, Subcutaneous tissue, Aponeurosis, Loose areolar tissue and Pericranium (see Fig. 13.1). Functionally, it can be considered as two layers:

- A superficial layer from the skin to the galea aponeurotica, and
- A deep layer consisting of areolar tissue and pericranium.

The aponeurosis is the key component to understanding these flaps. It is a thin, tendinous, sheet-like structure which provides the insertion for the occipitofrontalis muscle. Its attachment extends posteriorly, from the superior nuchal line round the superior temporal line, while more laterally it continues with the temporal fascia. This is a key area when raising a coronal flap. Anteriorly the "subaponeurotic space" extends into the upper eyelids, as there is no bony insertion. Here the loose subaponeurotic areolar tissue forms a potential space into which oedema, blood or (rarely) CSF can collect. Thus frontal fractures can be accompanied by a huge amount of eyelid swelling.

It is between these two functional layers that the scalp moves. If the scalp is traumatically avulsed (occasionally seen in industrial accidents where long hair is caught in machinery), separation occurs through the subgaleal plane. This may be advantageous in that the supplying vasculature passes through the more superficial tissues and can occasionally be reattached using microvascular techniques.

Most scalp lacerations extend the full thickness of the upper layer. Vessels and nerves lay in the subcutaneous tissue (anteriorly—supraorbital and supratrochlear; laterally—superficial temporal artery and auriculotemporal nerve; posteriorly—posterior auricular artery and occipital artery). These vessels anastomose freely with each other, providing a rich blood supply which can bleed profusely. To make matters worse (from a surgical perspective), the surrounding fibrous tissue prevents vasoconstriction. In children, bleeding from the scalp can therefore rapidly result in shock.

13.1.1 Anatomical Landmarks of the Facial Nerve

The extracranial part of the facial nerve exits the stylomastoid foramen, just in front of the mastoid process and passes into the parotid gland. Here it lies in a fibrous plane separating the deep and superficial lobes of the gland. The nerve then divides into two major divisions: an upper "temporal-facial" and lower "cervicofacial" branch. These then divide further into its five terminal branches. Frequent interconnections exits between these branches—the "pes anserinus."

The uppermost of the five terminal branches (temporal or frontal branch) passes upwards and forwards into the forehead. It is this branch which is mostly at risk when raising a coronal flap, although traction palsy of the entire nerve can occur if the flap is retracted too aggressively. To avoid injury to the upper branch, two landmarks are useful:

1. A point 1 cm in front of the tragus (or alternatively the upper attachment of the pinna)
2. A point 1 cm lateral and 2 cm above the lateral end of the eyebrow

A line joining these points is a rough indication of where the nerve is. It also indicates where the temporalis fascia will be incised (see Figs. 13.2 and 13.3). Variations in these landmarks have been reported. All of them are just a guide. Above and behind this line the nerve should be safe from deep dissection, although it is still at risk from traction.

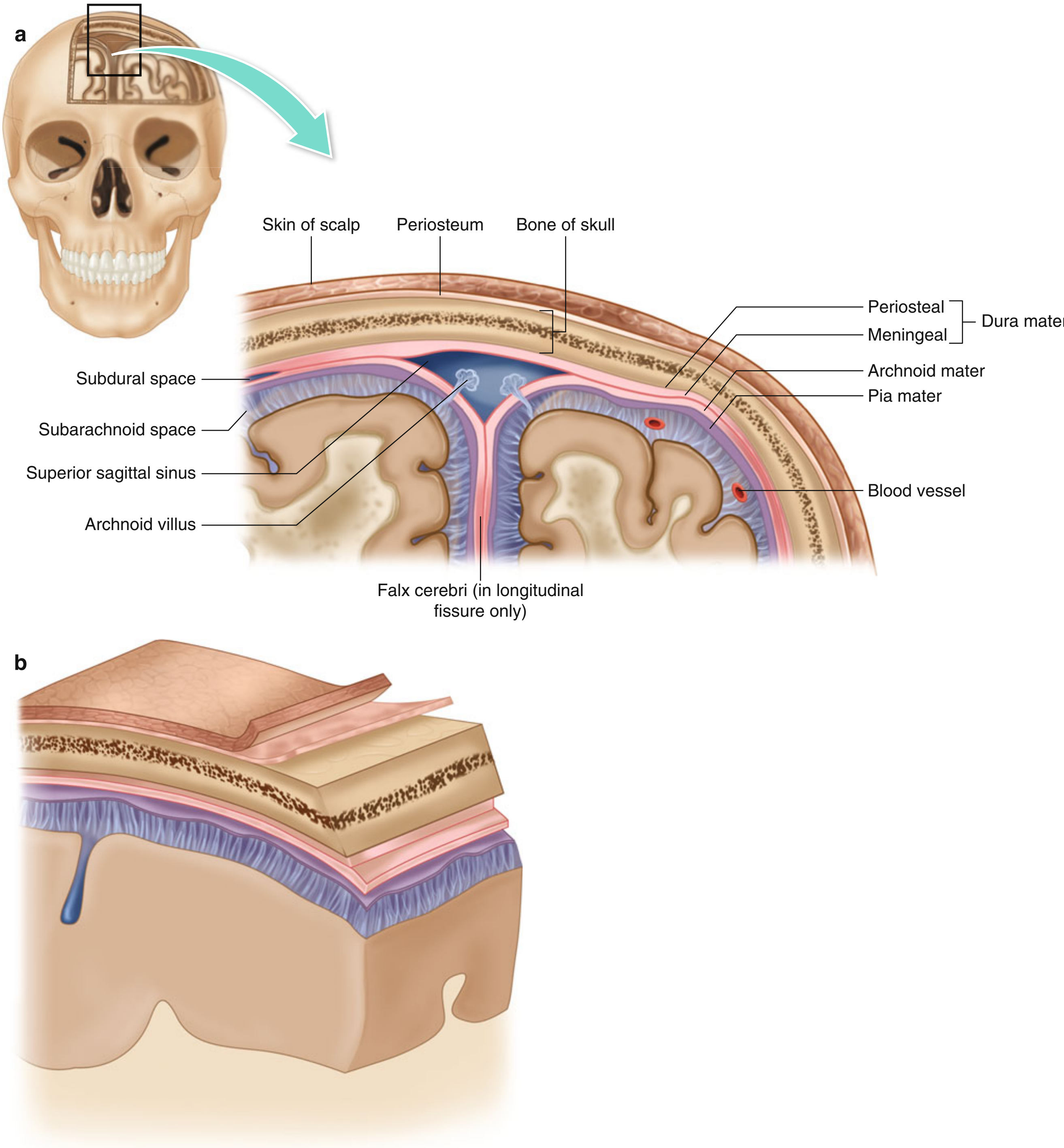

Fig. 13.1 (**a**, **b**) Layers of the S.C.A.L.P. Anatomically there are five, but functionally they are considered as just two

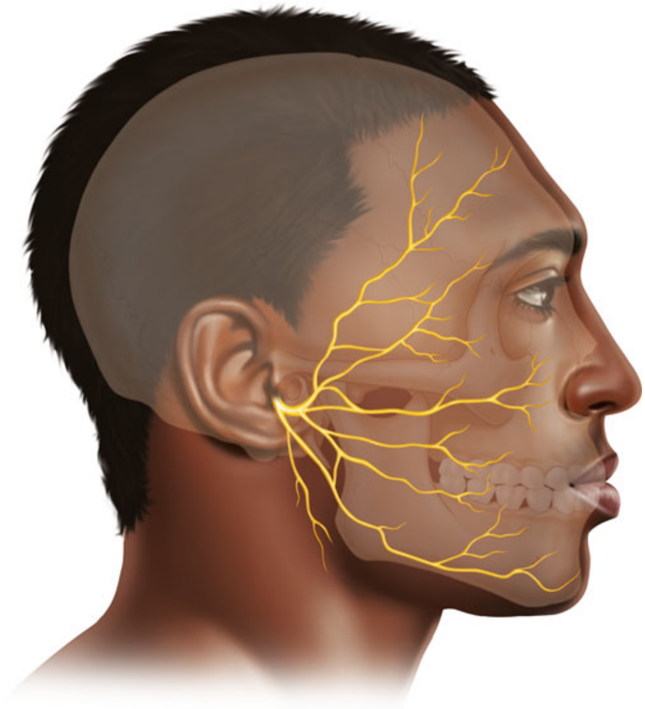

Fig. 13.2 Extracranial course of the facial nerve (CN VII)

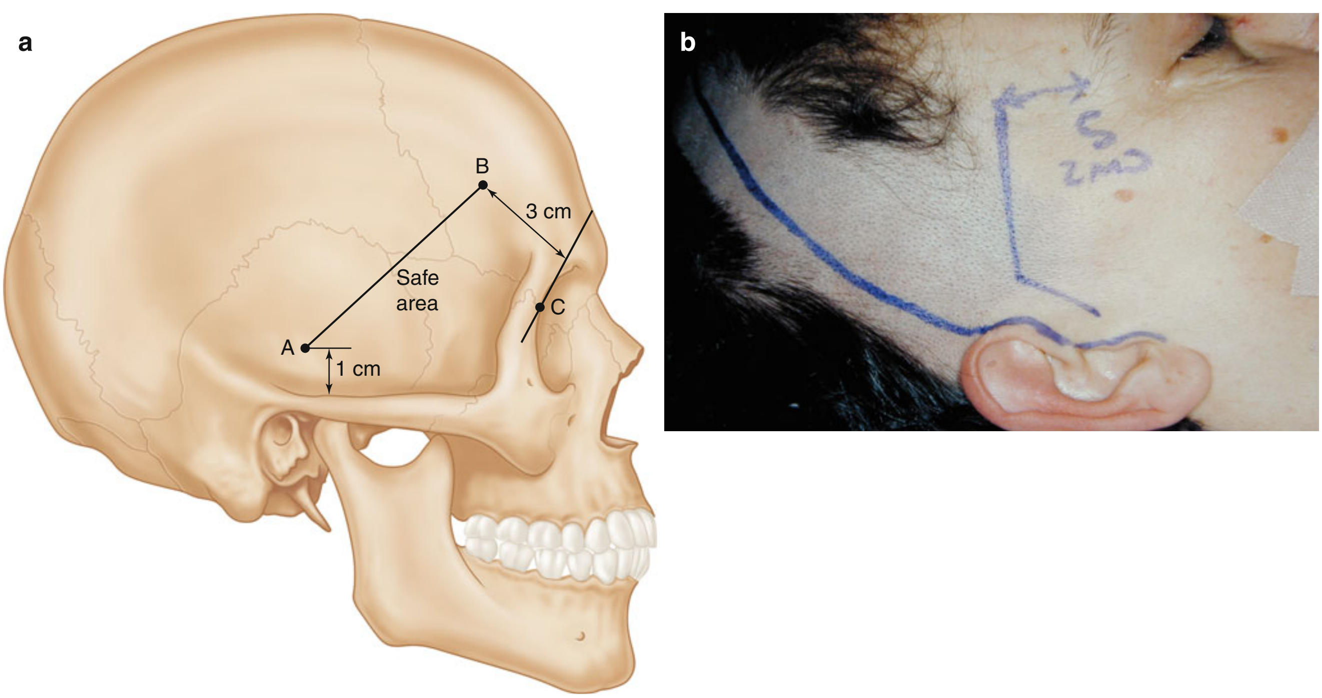

Fig. 13.3 (**a**, **b**) Useful landmarks to avoid injury to the upper branch of the facial nerve (several exist; two are shown here). Remember, these are just a guide

13.2 Surgical Technique

Raising a coronal flap can be considered in two parts:

1. Raising the central portion of the scalp, and
2. Dissection in the temporalis region bilaterally.

Which of these is done first is not crucial, but a degree of alternation between the two may be required. In the case shown (see Figs. 13.4, 13.5 and 13.6), temporalis dissection is started first. A skin incision is commenced at the lower attachment of the pinna, passing upwards towards the upper attachment. From there it passes into the lateral hair-bearing portion of scalp, gently curving backwards and upwards. Some surgeons prefer to pass the incision in front of the tragus in a suitable skin crease; others will pass the incision around the edge of tragus in order to maximise the cosmetic benefits. The incision is deepened down to the zygomatic arch and the attachment of the temporalis fascia along its upper border. If the plane of dissection is just in front of the tragal cartilage this is relatively avascular. This is then repeated on the other side.

Case 1

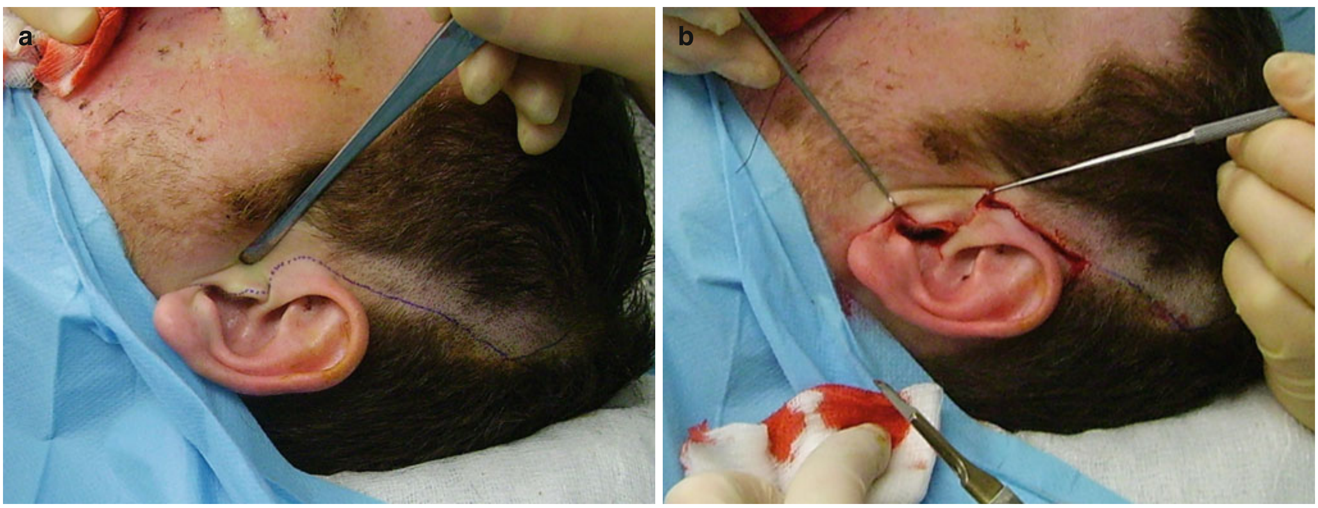

Fig. 13.4 (**a**, **b**) Preauricular skin markings and initial incision. In this case, these pass behind the tragus (to minimise visible scarring). Alternatively they can pass along a suitable pretragal skin crease

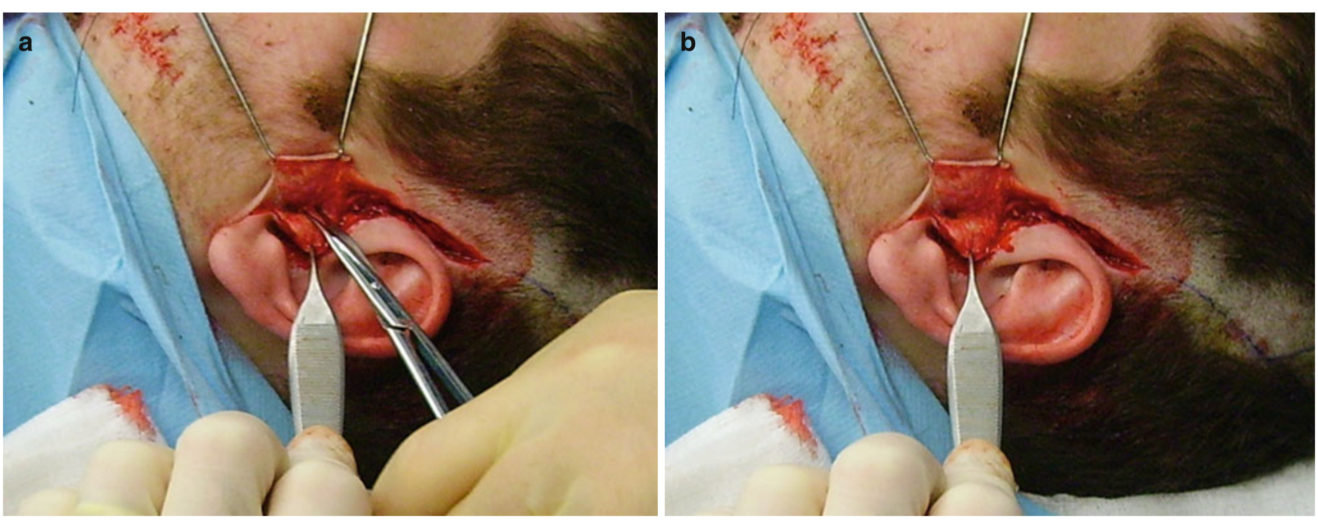

Fig. 13.5 (**a**, **b**) Initial dissection along the pretragal plane towards the zygomatic arch. This is usually a relatively quick part of the dissection. The plane is generally avascular

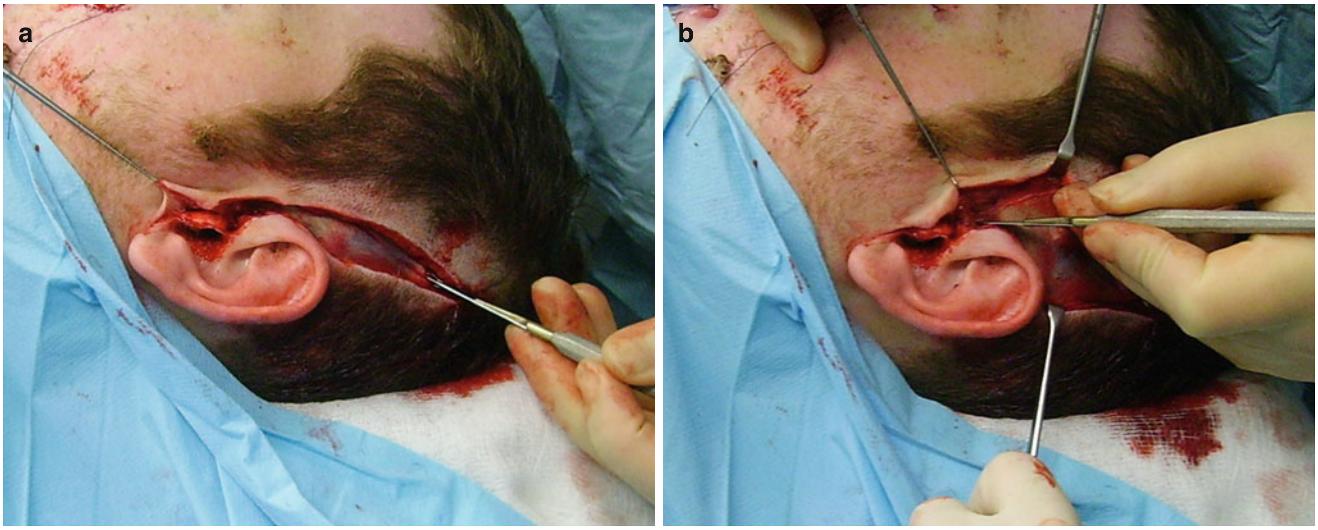

Fig. 13.6 (**a**, **b**) The incision is extended upwards through the full thickness of the scalp to expose the temporalis fascia

The upper part of the skin incision is then continued across the vertex of the scalp to meet its counterpart on the other side. This part of the scalp incision can vary considerably. In male pattern baldness an incision can be placed quite posteriorly, near to the occipital region if necessary so that it remains in hair-bearing scalp. A zigzag (as shown here), or "lazy S" configuration can also be used to help hide the scar whenever the hair is wet. The incision needs to be full thickness to include the entire thickness of the functional layer (the galea), otherwise the flap will not raise easily. This part of the procedure requires careful haemostasis as the scalp is highly vascular. Either careful diathermy or Raney clips applied to the scalp are effective methods. Because of the propensity to bleed it may be easier to make the incision in sections, obtaining haemostasis as you go, rather than all the way across scalp.

The scalp is then carefully elevated off the underlying periosteum. The plane of dissection here is the loose connective tissue between the galea and periosteum. This part of the dissection is quite easy and rapid. Some surgeons may inject saline into this plane prior to incision to facilitate elevation, a technique known as "hydrostatic dissection" or "hydrodissection." However, in the presence of underlying skull fractures, this should be done with caution. A large scalpel blade helps prevent tears in the underlying periosteum, a layer which may be useful in the repair of frontal sinus injuries or CSF leaks. As the scalp flap is slowly drawn forwards, the temporalis fascia comes into view laterally (see Figs. 13.7, 13.8, 13.9 and 13.10).

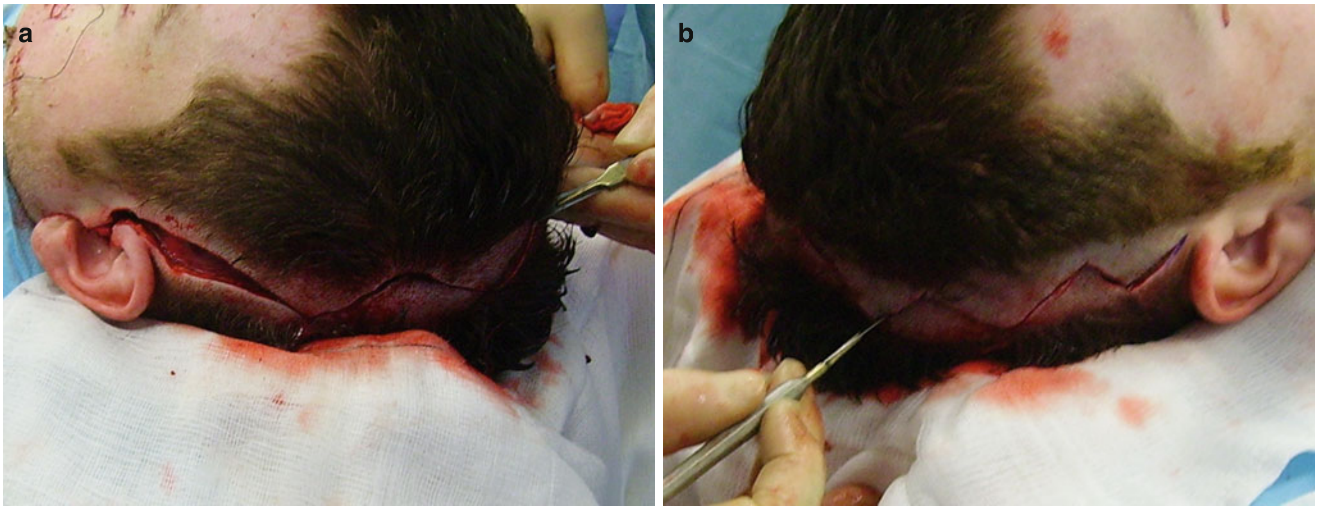

Fig. 13.7 (**a**, **b**) Full thickness "zig-zag" scalp incision. Incise down to (but not through) the pericranium

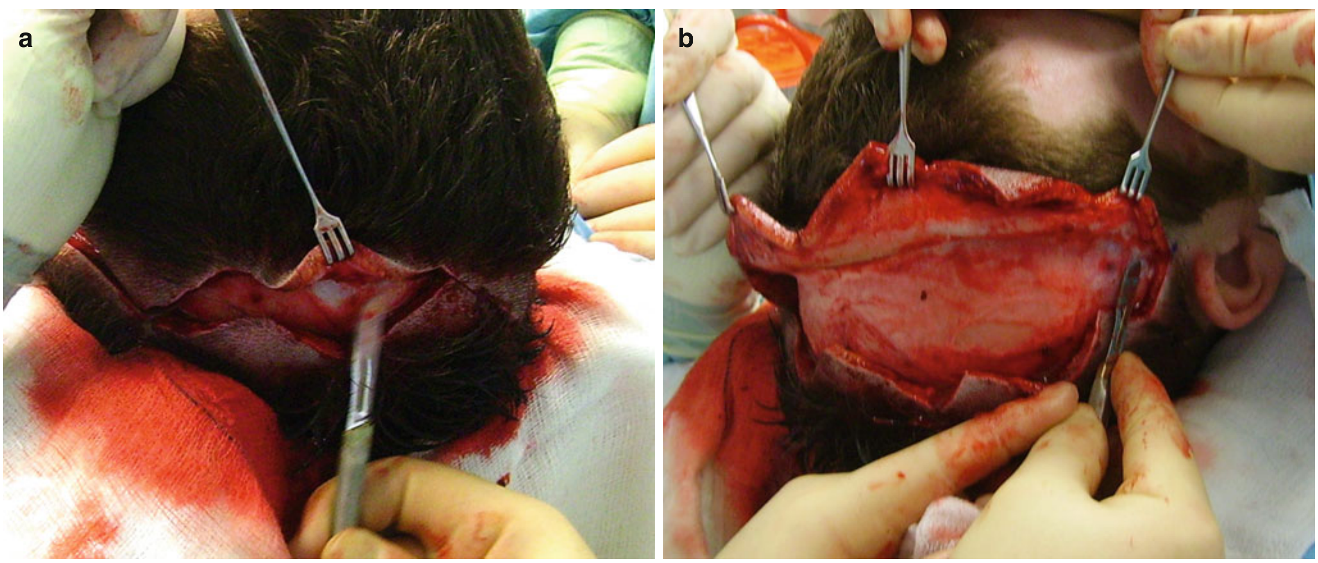

Fig. 13.8 (**a**, **b**) Initial elevation of scalp. A large blade (no. 10) can be used to incise the loose areolar tissue. Alternatively this can be done with cutting diathermy

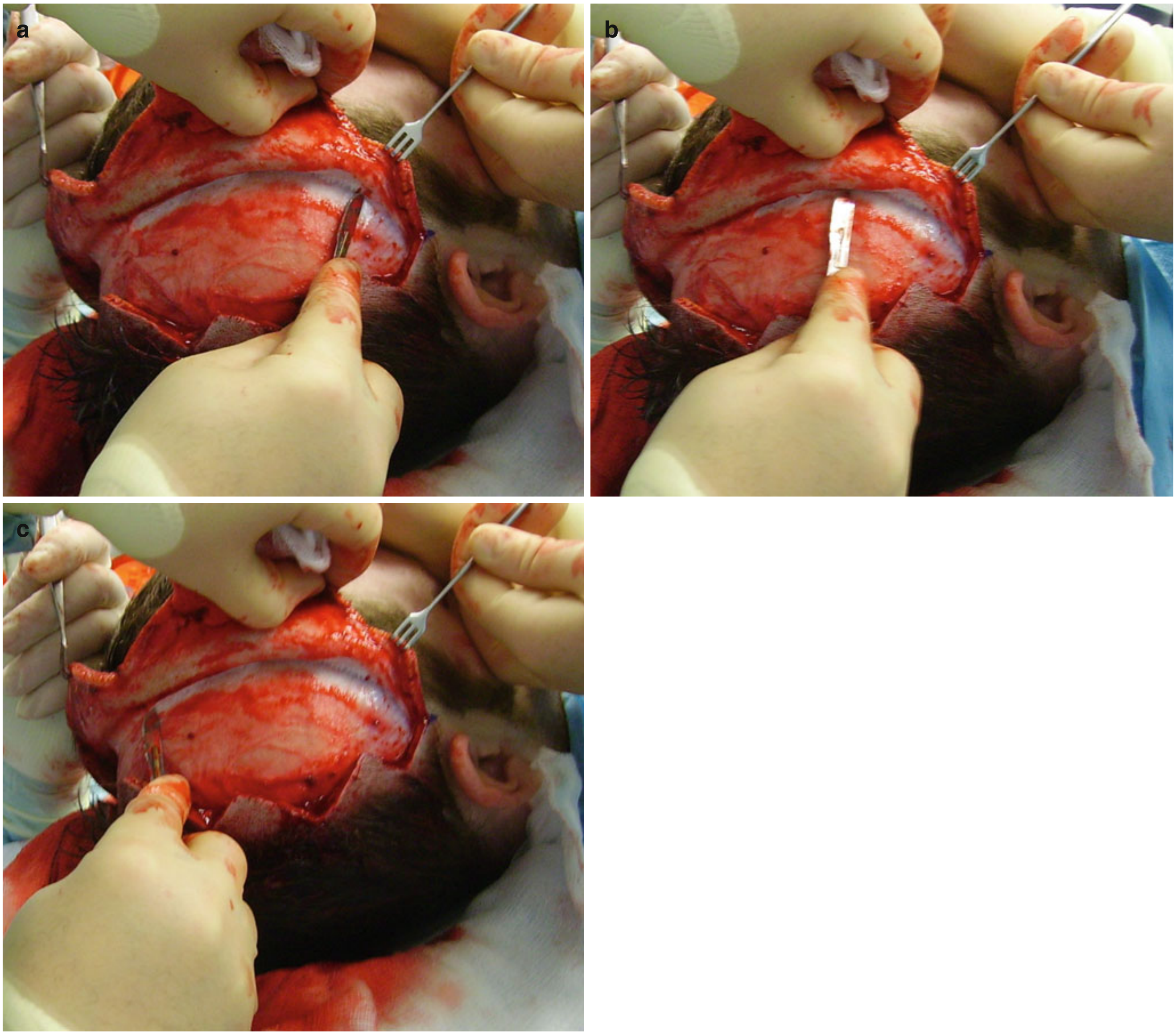

Fig. 13.9 (**a**–**c**) As the scalp flap begins to evert, long sweeping cuts will raise this rapidly. A bit like sheep shearing!

Fig. 13.10 Flap raised sufficiently to expose temporalis fascia. Proposed incision through the fascia is marked (see text for landmarks)

The temporalis fascia is then incised and its outermost layer bought forwards and down, along with the scalp. This part of the dissection requires careful attention. The fascia is quite adherent along the temporal crest. Placement of the incision in the temporalis fascia can vary but corresponds to the landmarks previously described for the upper branch of the facial nerve. Depending upon the patient's body habitus, the temporalis fascia may have two easily recognisable layers separated by fat. Or they may be almost fused together as a single layer, which needs to be lifted as one layer exposing the underlying muscle. This does not seem to be a clinical problem postoperatively. The entire scalp is reflected forwards, over the patient's face until a horizontal line approximately 2 cm above the super orbital ridges is reached. Attention is then turned to the periosteal layer (see Figs. 13.11, 13.12 and 13.13).

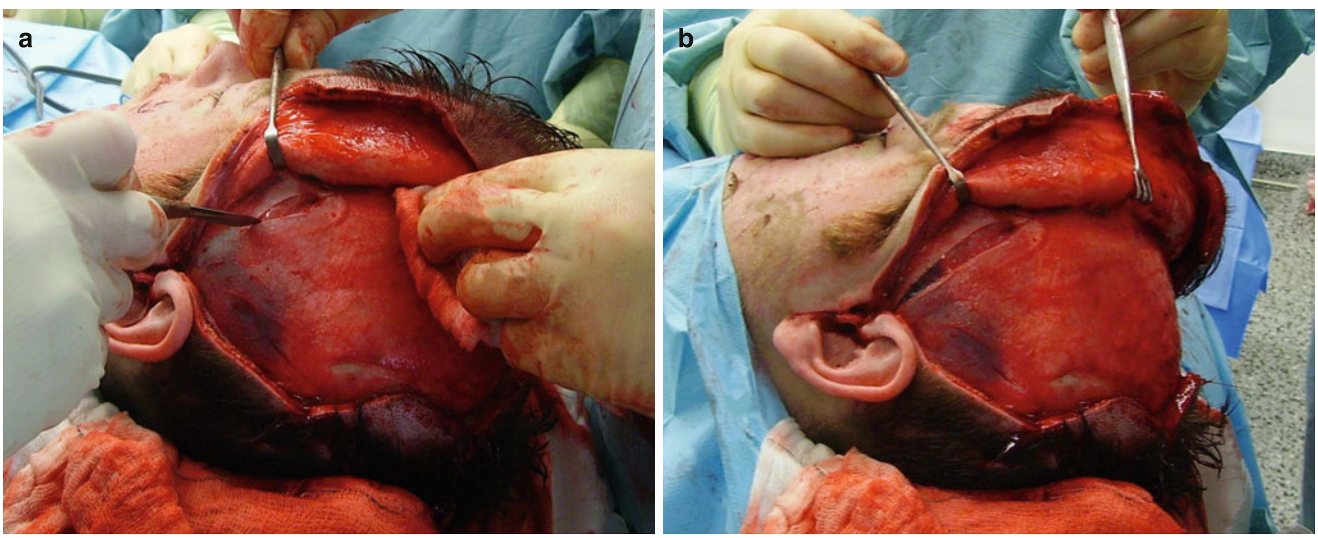

Fig. 13.11 (**a**, **b**) Temporalis fascia is incised. This is variably described in the literature. Sometimes there are two layers (separated by a thin layer of fat). Other times there is only one layer actually discernible, as shown here. The underlying temporalis muscle comes into view

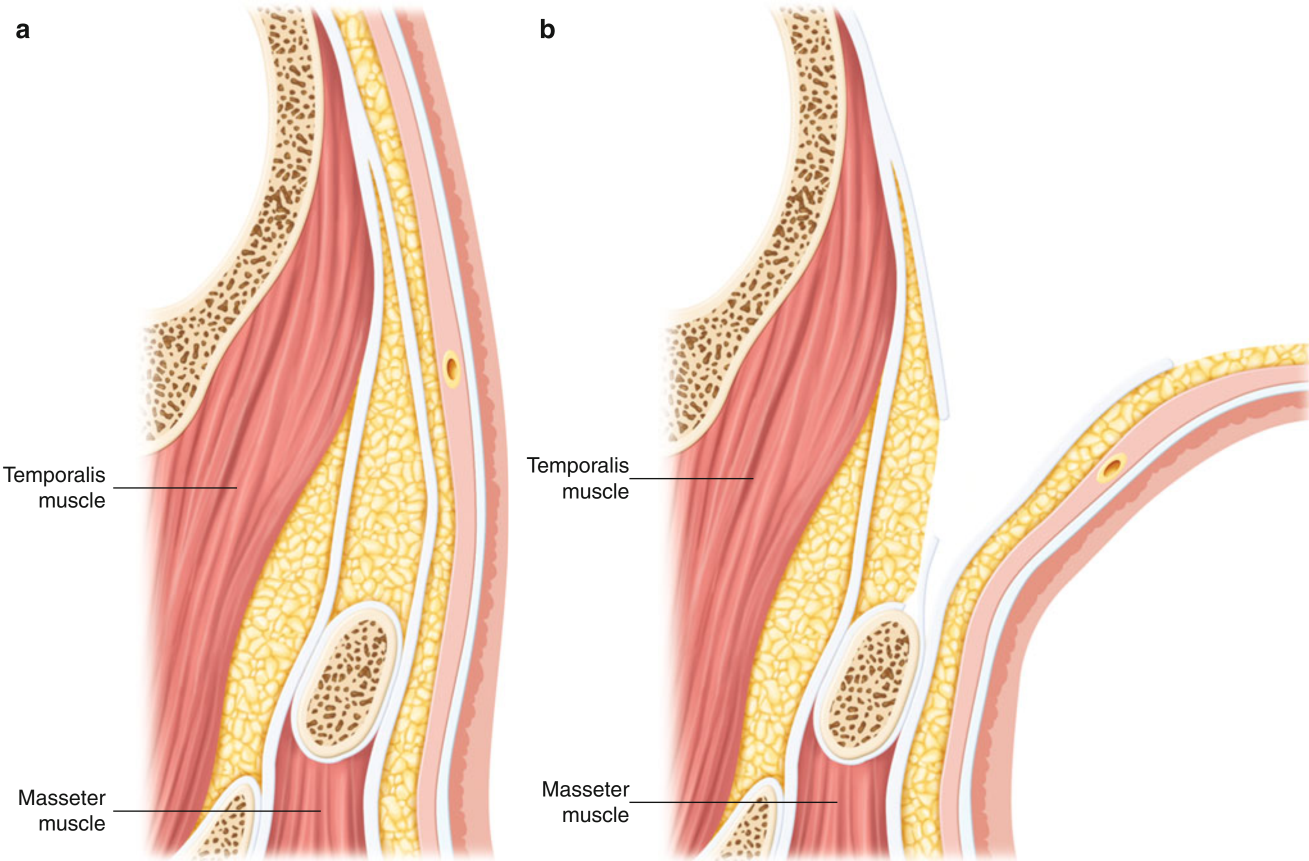

Fig. 13.12 (**a**, **b**) Cross-sectional view of zygomatic arch invested by split layers of temporalis fascia

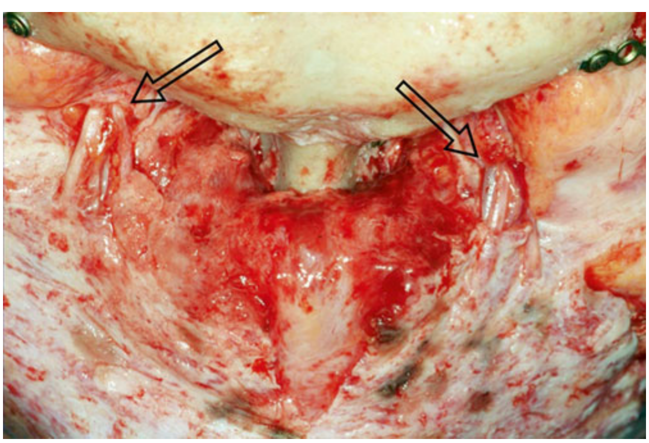

Fig. 13.13 Flap is everted, showing bridge of nose flanked either side by supraorbital neurovascular structures (*arrows*)

Returning to the vertex of the head, the periosteum is incised to produce a generous "periosteal flap." This is sometimes useful in fracture repair. This flap is raised as a second separate layer using a periosteal elevator. Completion of exposure of the upper face and forehead is done by raising both the periosteal and galeal flaps together as a single layer over the last 2 cm above the supraorbital ridges.

Alternatively, some surgeons simply incise the periosteum just above the ridges and leave the rest in place. Whichever approach is decided, care is required in this area as the supraorbital and supratrochlear nerves will come into view and are at risk. They may run through either notches or tunnels in the brow region. If they are in a small tunnel this can be simply osteotomised allowing the nerve to drop out (see Fig. 13.13).

Depending upon the exposure required, periosteal elevation along the zygomatic arch may also be necessary. In extensive fractures the entire zygomatic arch, lateral orbital rim, and much of the zygomatic prominence can be exposed. Bringing the coronal flap forwards can expose the nasoethmoid region, most of the nasal bones and the upper two thirds of the medial and lateral orbital walls, as well as the orbital roof. When fully raised, further mobilisation of flap is essentially limited by traction on the optic nerve and contents of the superior orbital fissure as well as traction on the facial nerves. Nevertheless, a well-raised flap can provide excellent access with little risk to these structures (see Figs. 13.15–13.22).

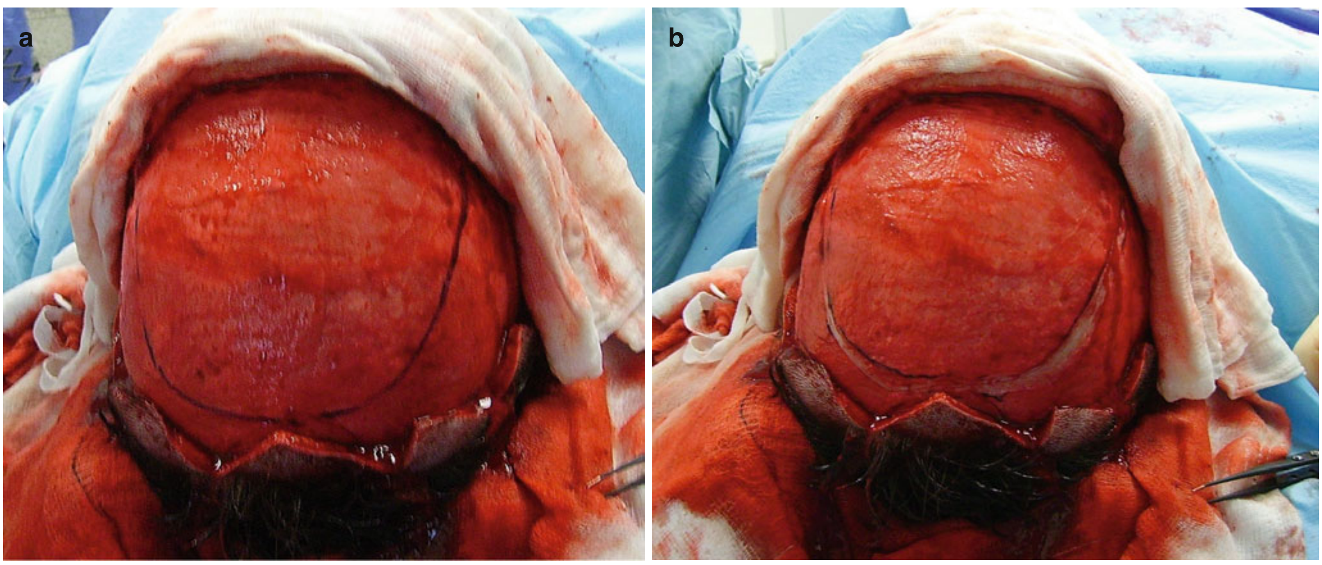

Fig. 13.14 (**a**, **b**) Initial marking and incision for pericranial flap

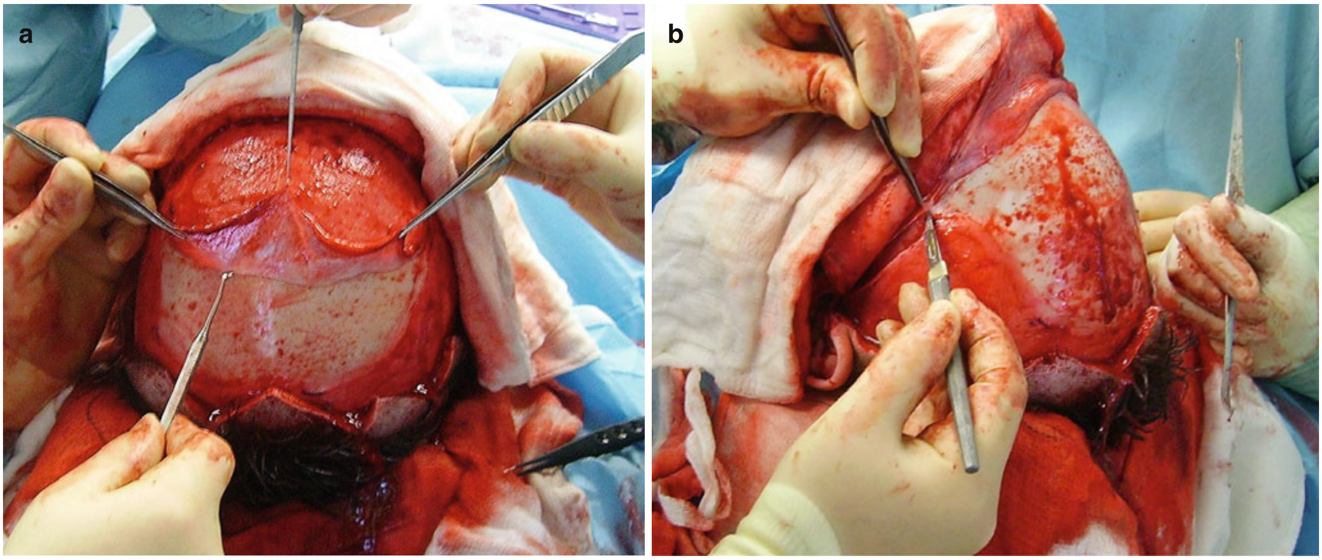

Fig. 13.15 (**a**, **b**) Pericranial flap is raised quickly with a periosteal elevator. Be very careful if there are any underlying fractures. This layer can sometimes be very thin and be easily button-holed. As this layer reaches the incised temporalis fascia, the two can be bought forward "en masse"

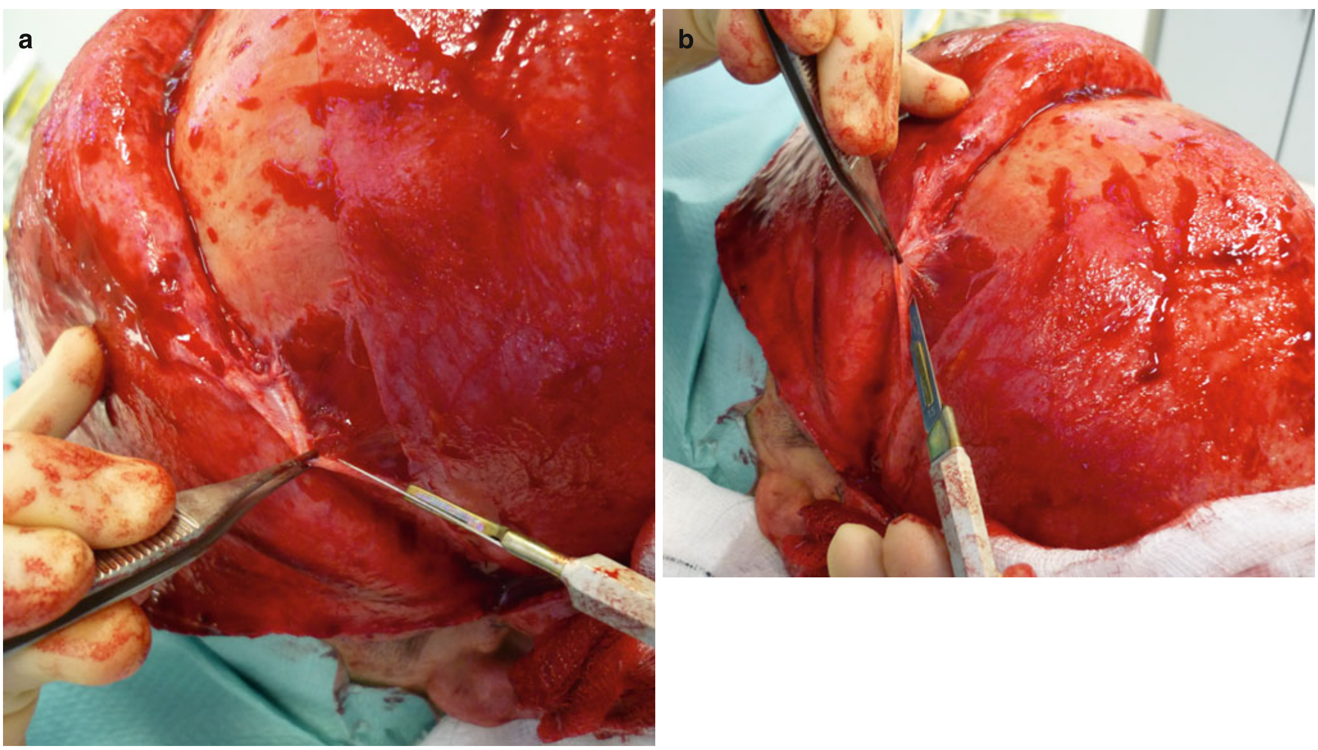

Fig. 13.16 (**a**, **b**) The temporalis fascia is carefully dissected off the muscle. This takes a little time and can be a bit tricky

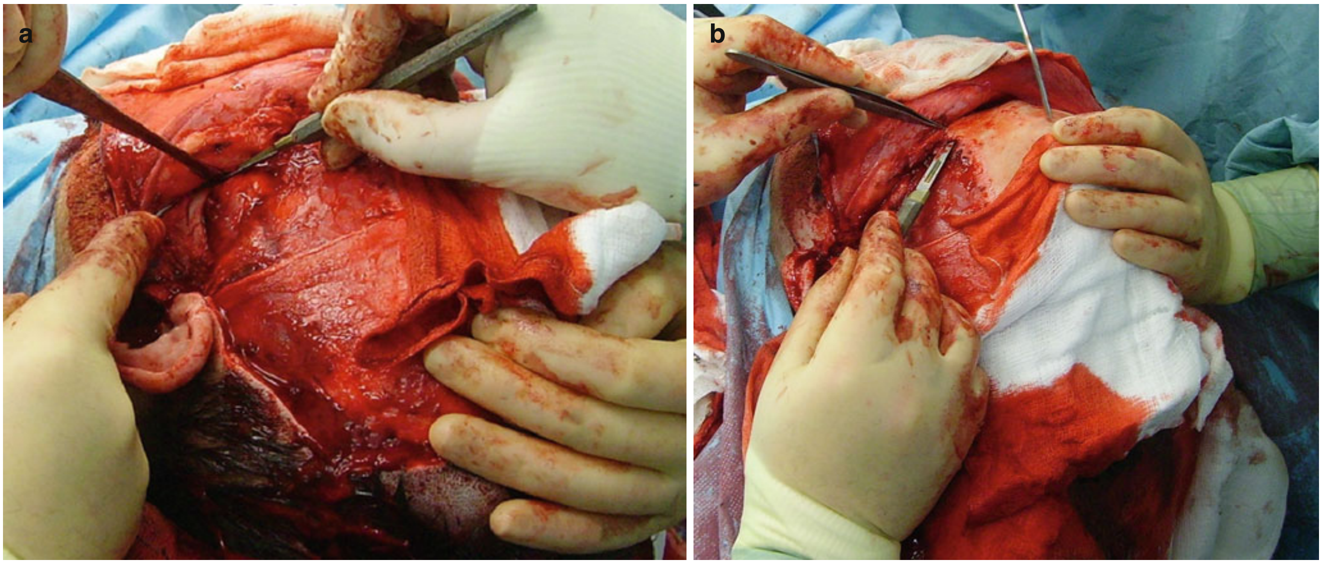

Fig. 13.17 (**a**, **b**) The temporalis fascia is taken forward to expose the arch and lateral orbital rim. With further dissection, the entire arch and zygomatic body can be exposed

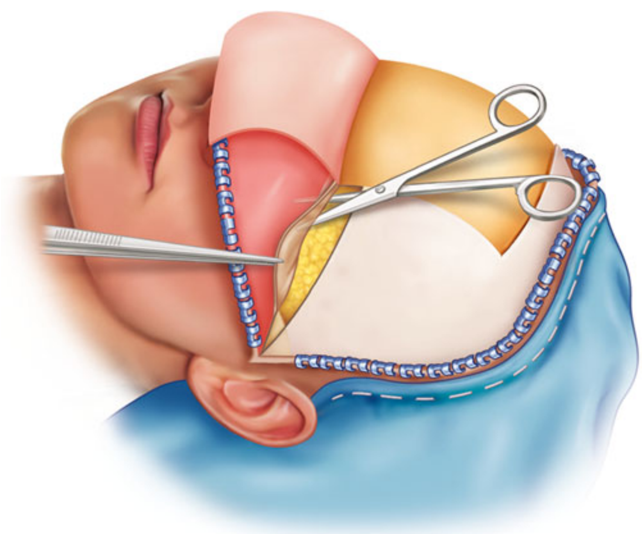

Fig. 13.18 Schematic diagram showing scalp flap and pericranial layer being bought forward along with temporalis fascia

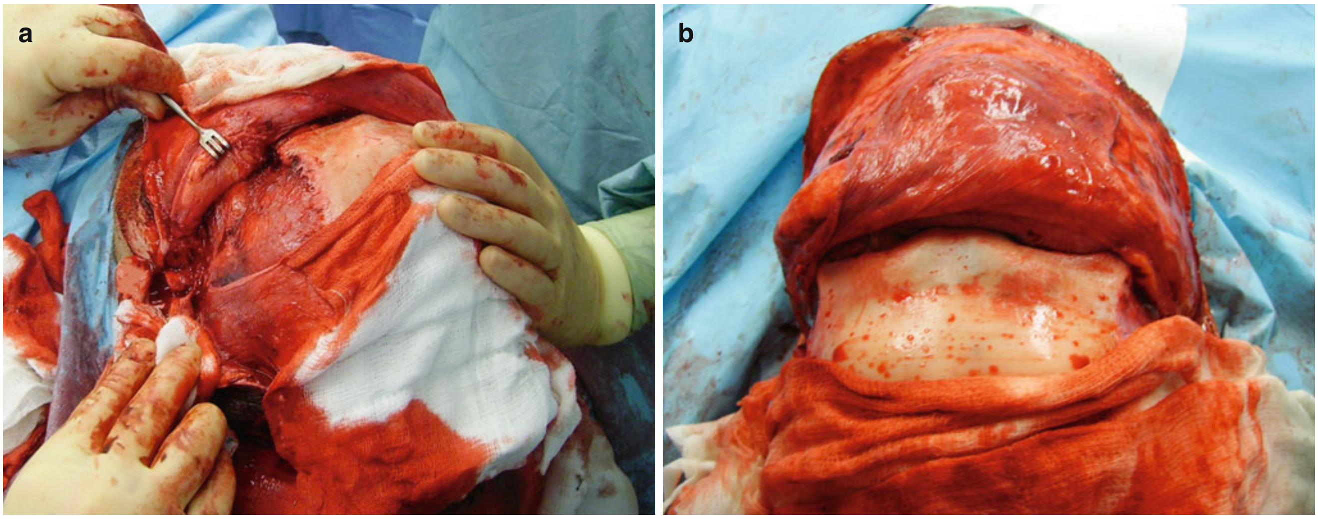

Fig. 13.19 (**a**, **b**) Flap everted to expose arch and supraorbital ridges

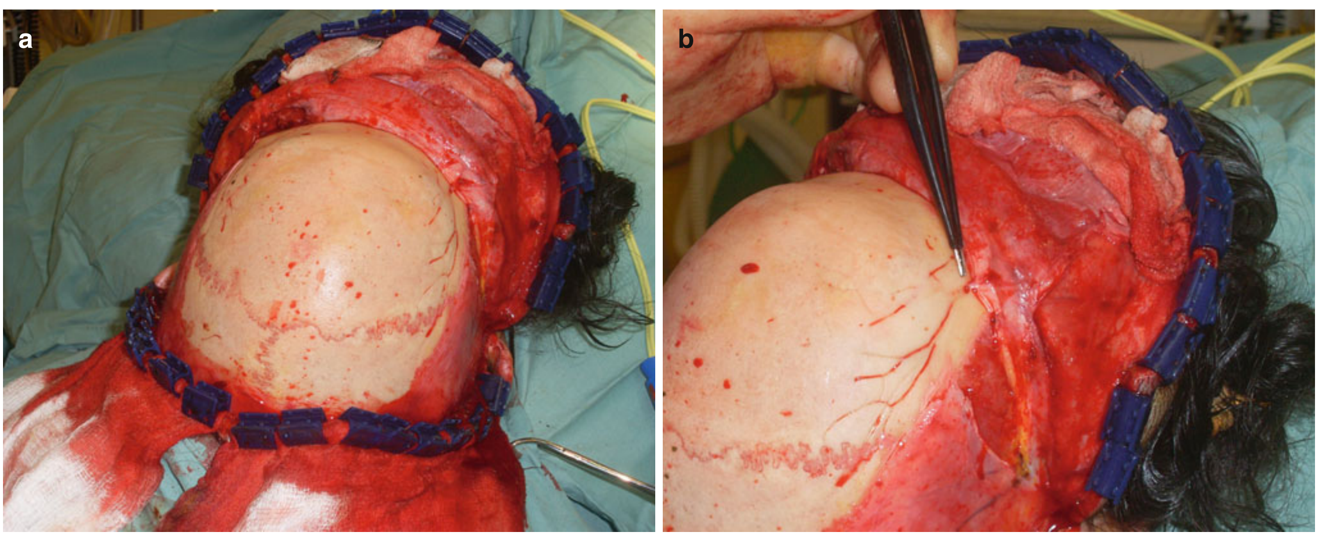

Fig. 13.20 (**a**, **b**) Another example showing small accessory vessels. These are too lateral to be the supraorbital or supratrochlear vessels and can be safely divided

Case 2

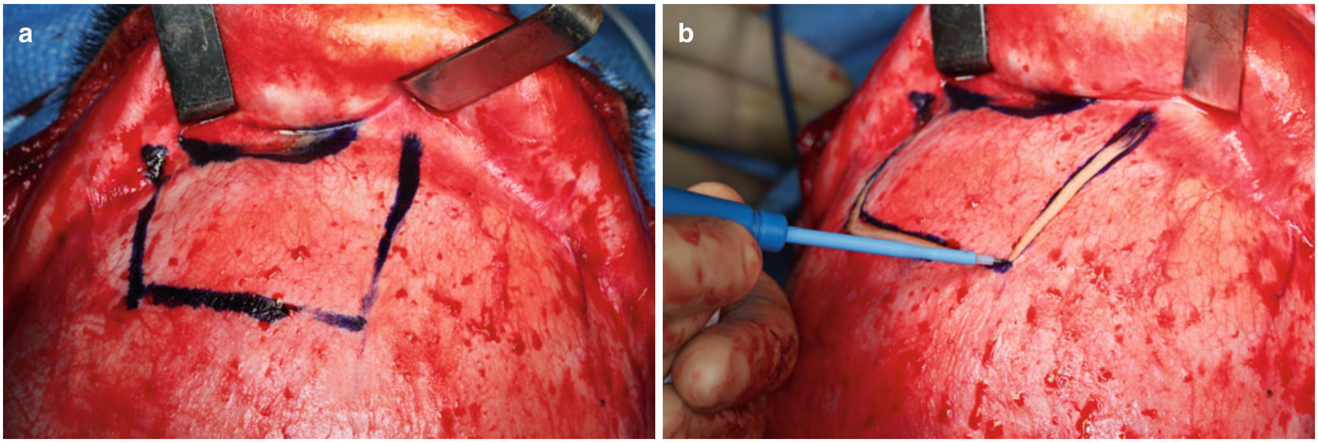

Fig. 13.21 (**a**, **b**) A much smaller pericranial flap is raised in this example. Only enough to expose the underlying fracture

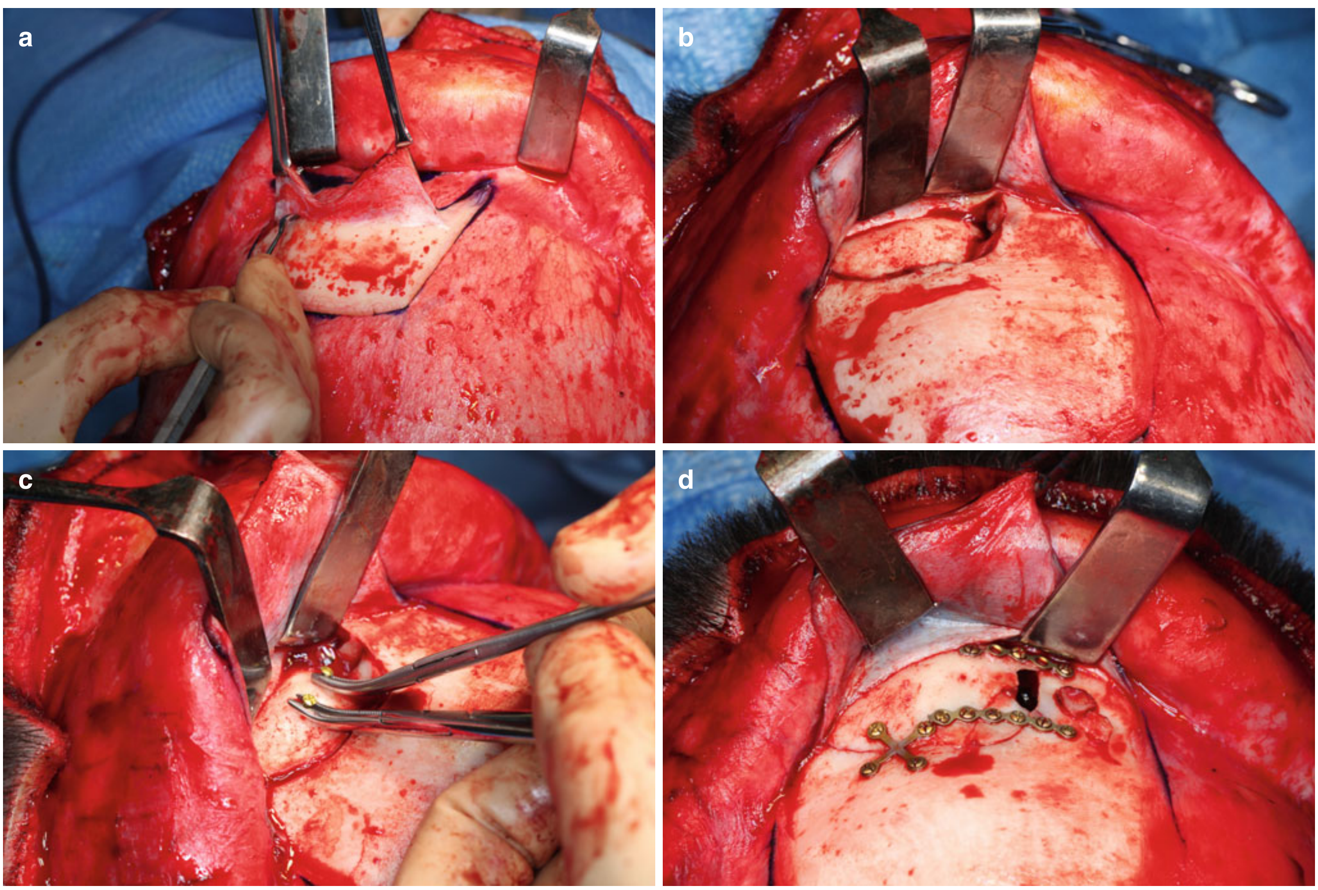

Fig. 13.22 (**a**–**d**) Pericranial flap is elevated, fracture identified, reduced (note technique of using screws for points of application), and plated

Case 3

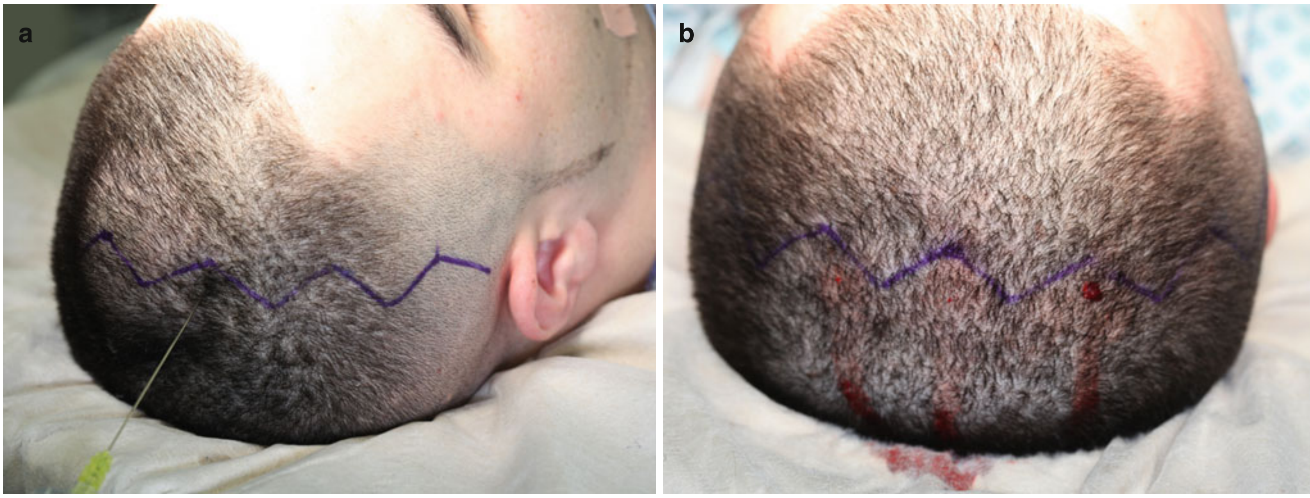

Fig. 13.23 (**a**, **b**) "Hydrodissection technique." See text for detail

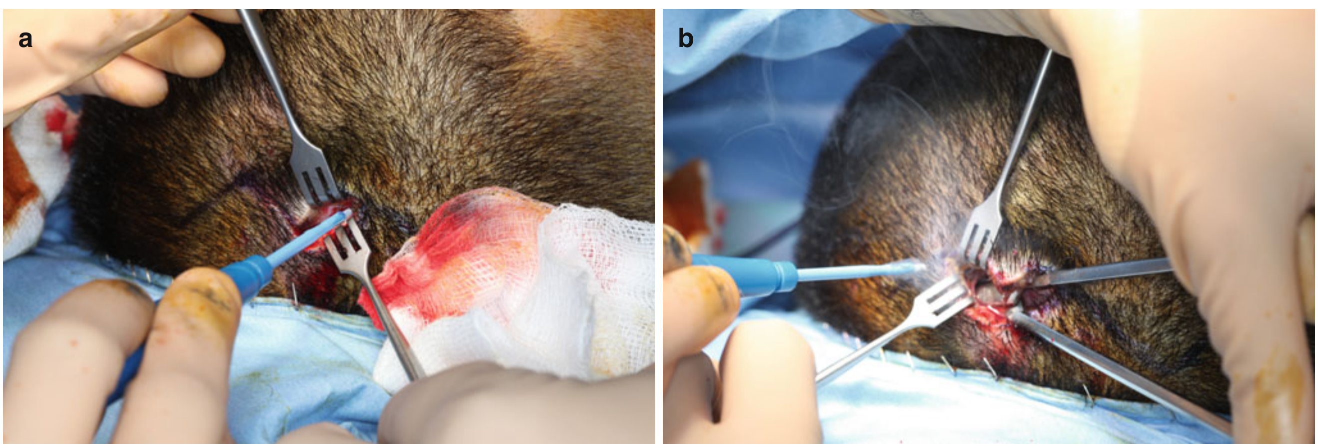

Fig. 13.24 (**a**, **b**) Initial incision using cutting diathermy

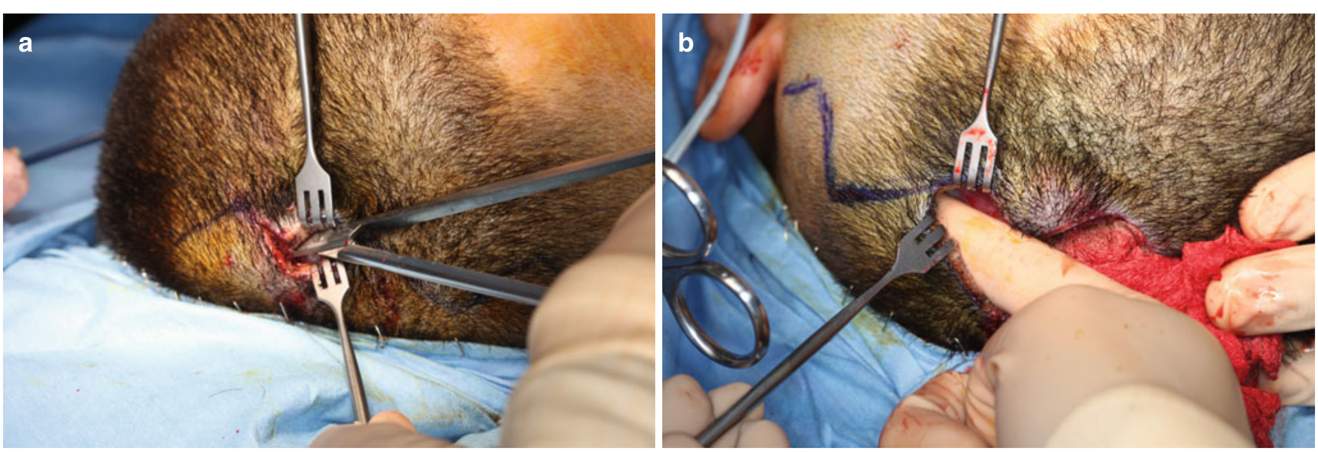

Fig. 13.25 (**a**, **b**) Alternative technique. Undermining of scalp with large scissors before incision

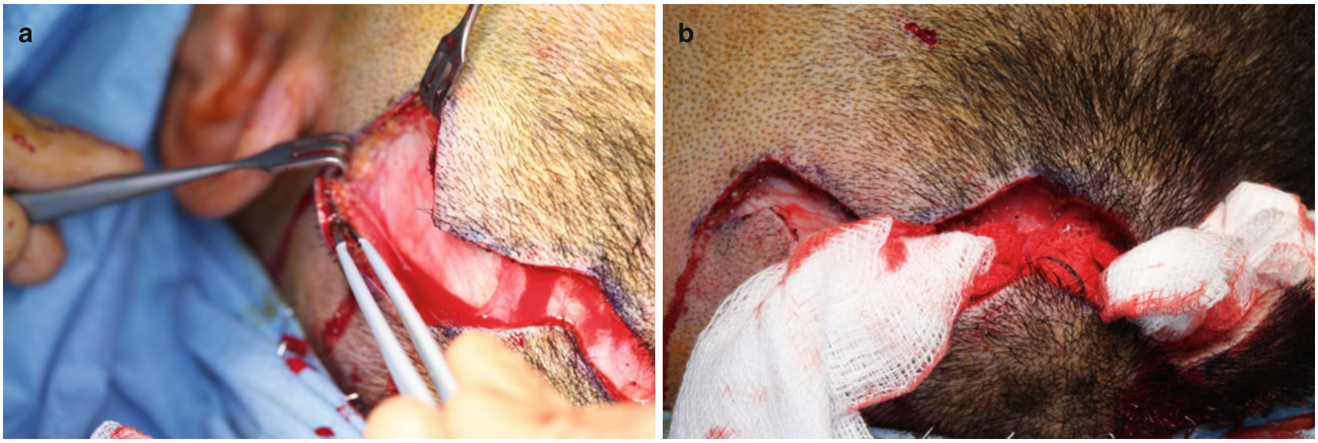

Fig. 13.26 (**a**, **b**) Haemostasis is essential. Blood loss can be significant. It can be achieved either with diathermy or Rene clips

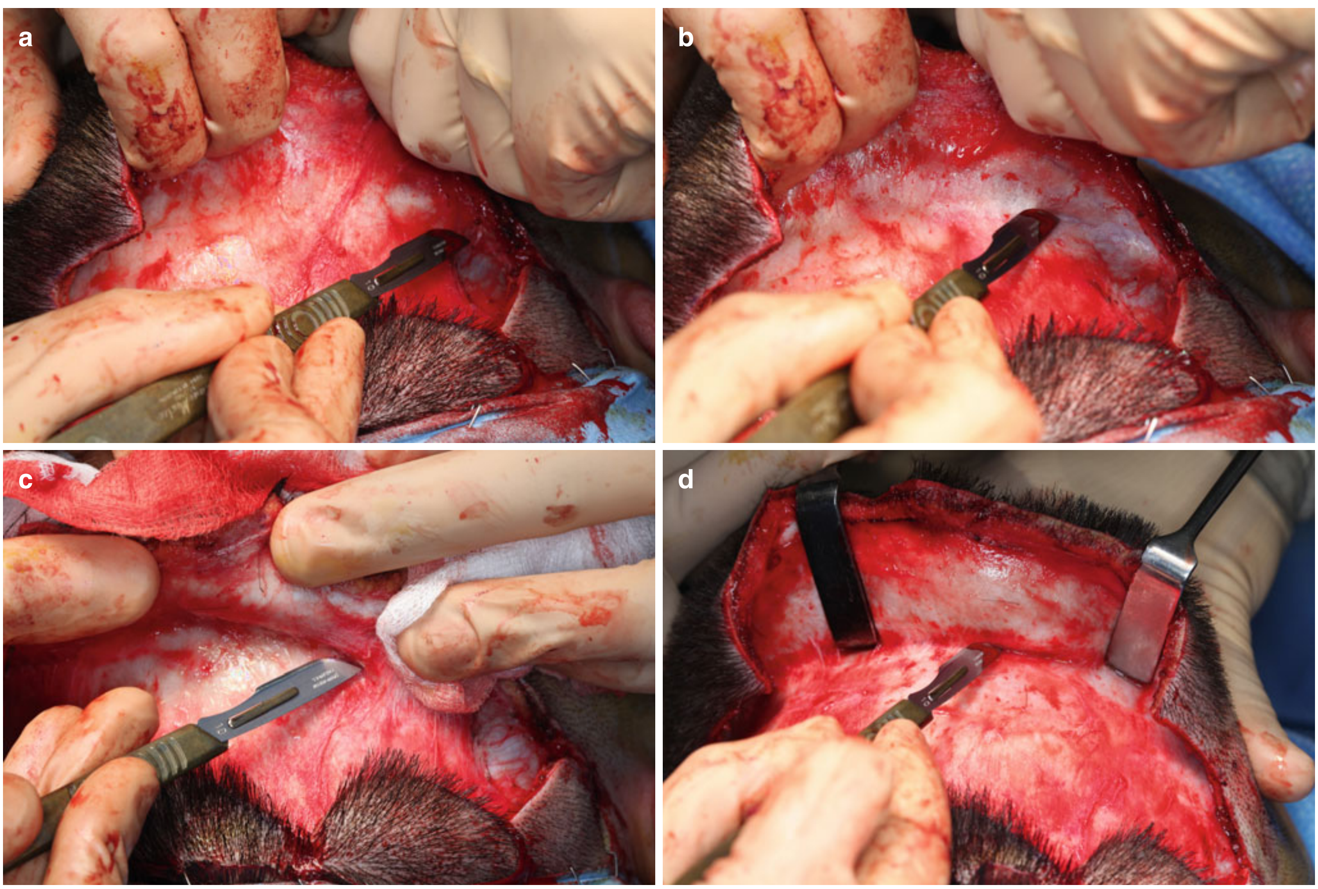

Fig. 13.27 (**a**–**d**) Rapid elevation with large blade

Fig. 13.28 (**a**–**e**) Pericranial flaps can be based centrally or laterally. In all cases try to maintain a broad base. The design depends on what the flap is going to be used for

Following such extensive degloving of the upper face, careful resuspension of the soft tissues is important during wound closure. Nonresorbable or slowly resorbable sutures should be used to resuspend the galea thereby preventing ptosis of the forehead. The temporalis fascia also needs to be carefully closed, although a watertight closure may be difficult with swelling of the tissues. This does not appear to be a clinical problem. Suction drains or a pressure dressing may be used to prevent haematoma formation (see Figs. 13.29 and 13.30).

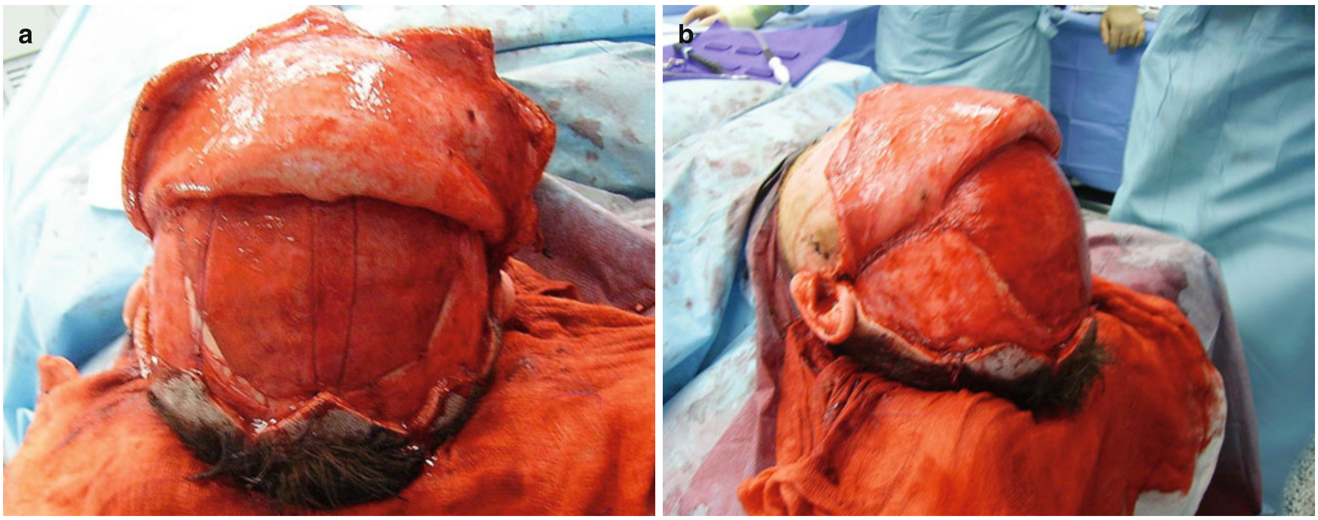

Fig. 13.29 (**a**, **b**) Resuspension sutures and closure of the temporalis fascia reduce "sagging" of the soft tissues (especially the brow) postoperatively

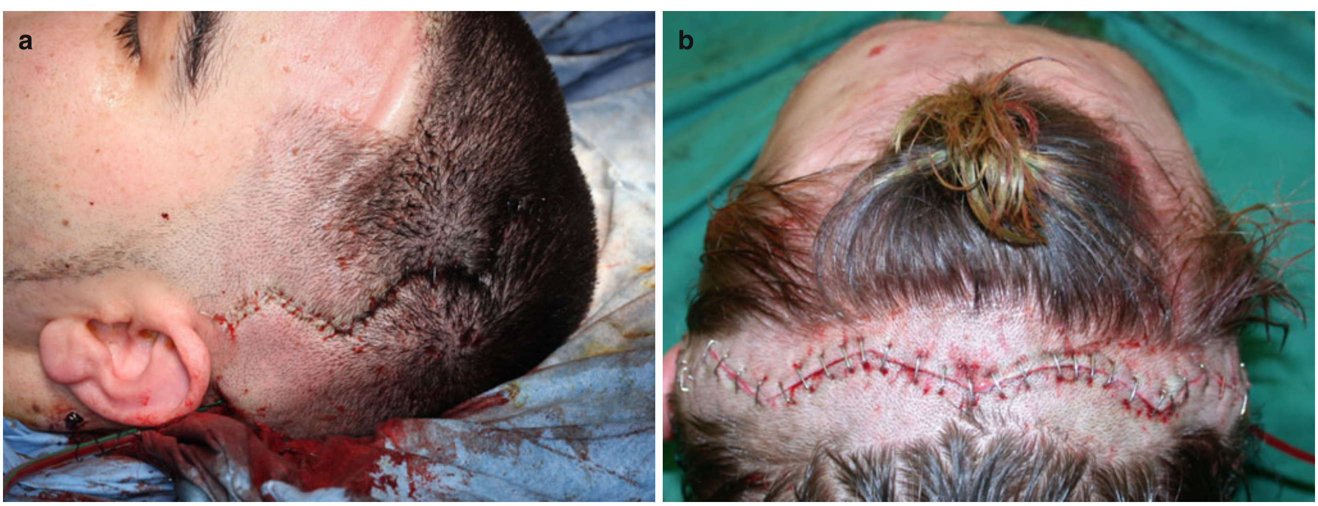

Fig. 13.30 (**a**, **b**) Skin can be closed with sutures or clips

Case 4

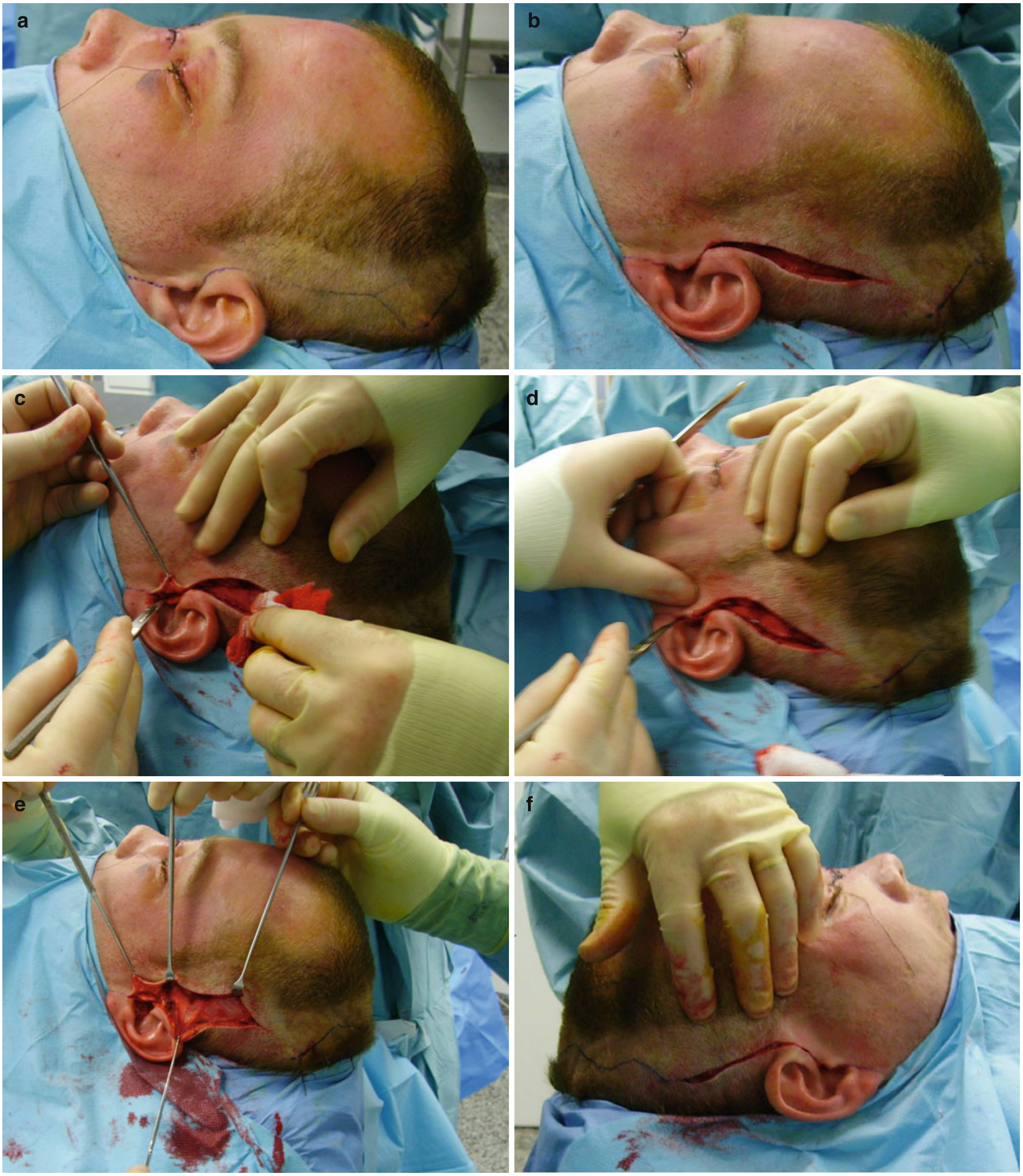

Fig. 13.31 (**a**–**o**) A well-raised flap can provide excellent exposure of the zygoma

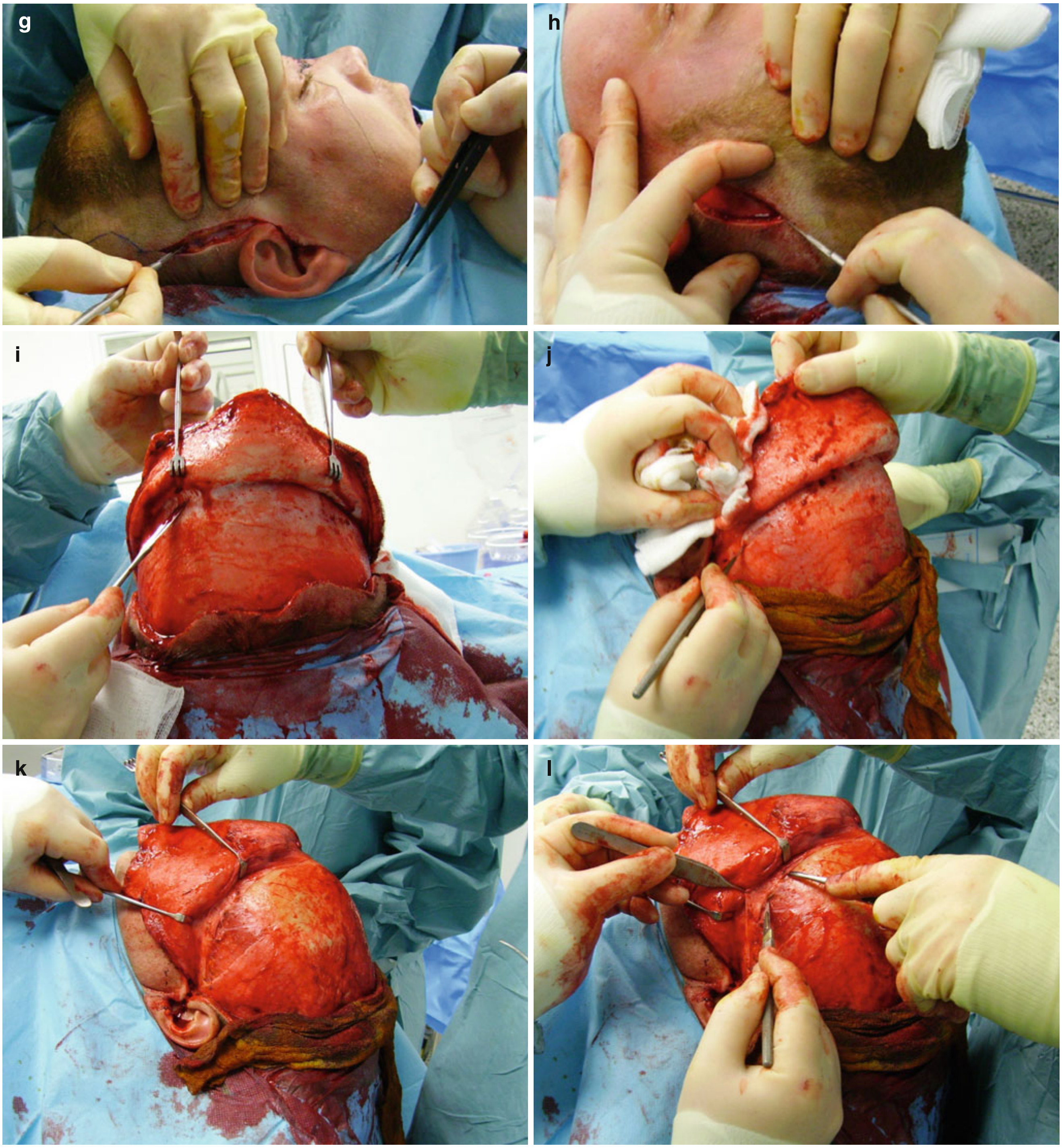

Fig. 13.31 (continued)

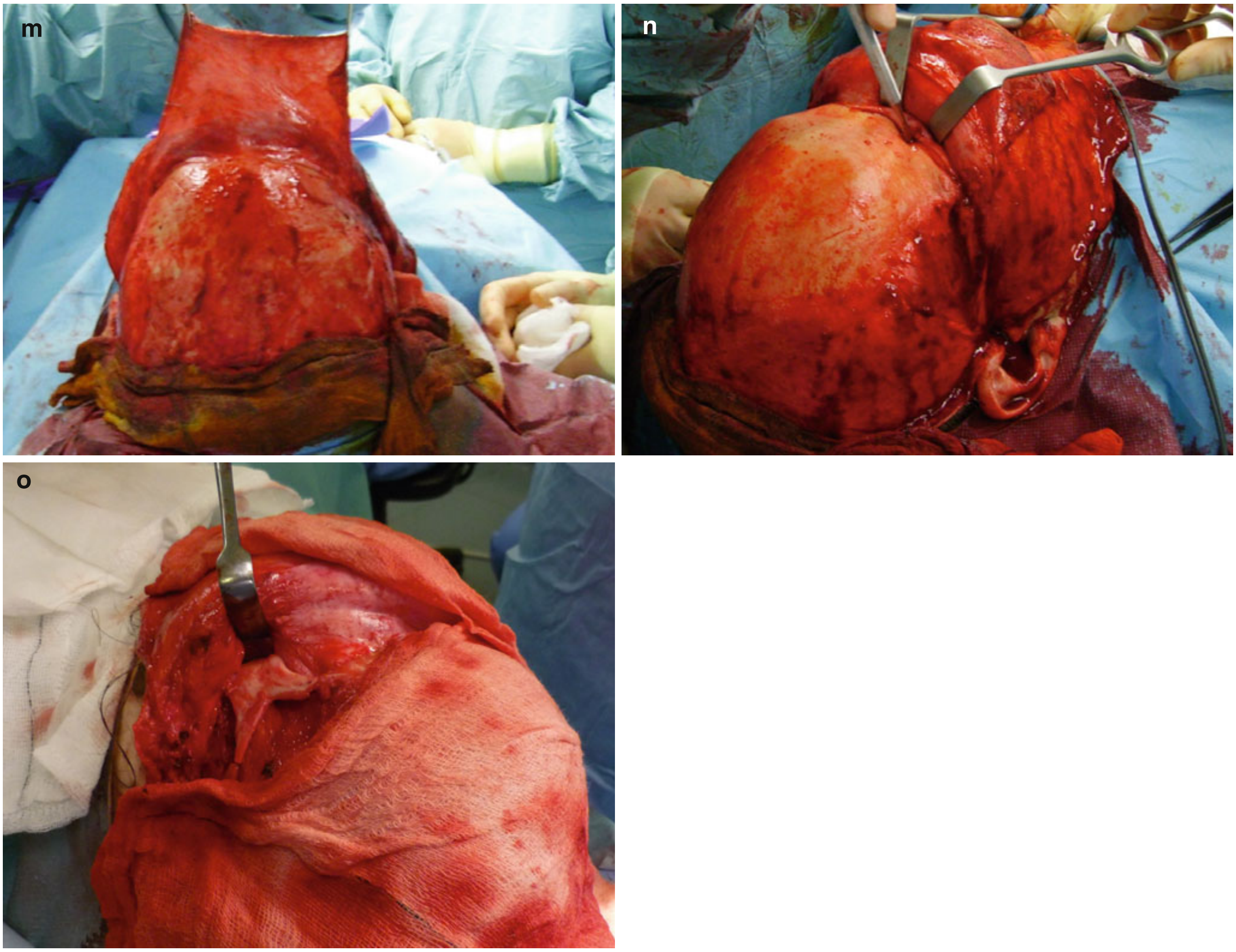

Fig. 13.31 (continued)

Cases 5 and 6

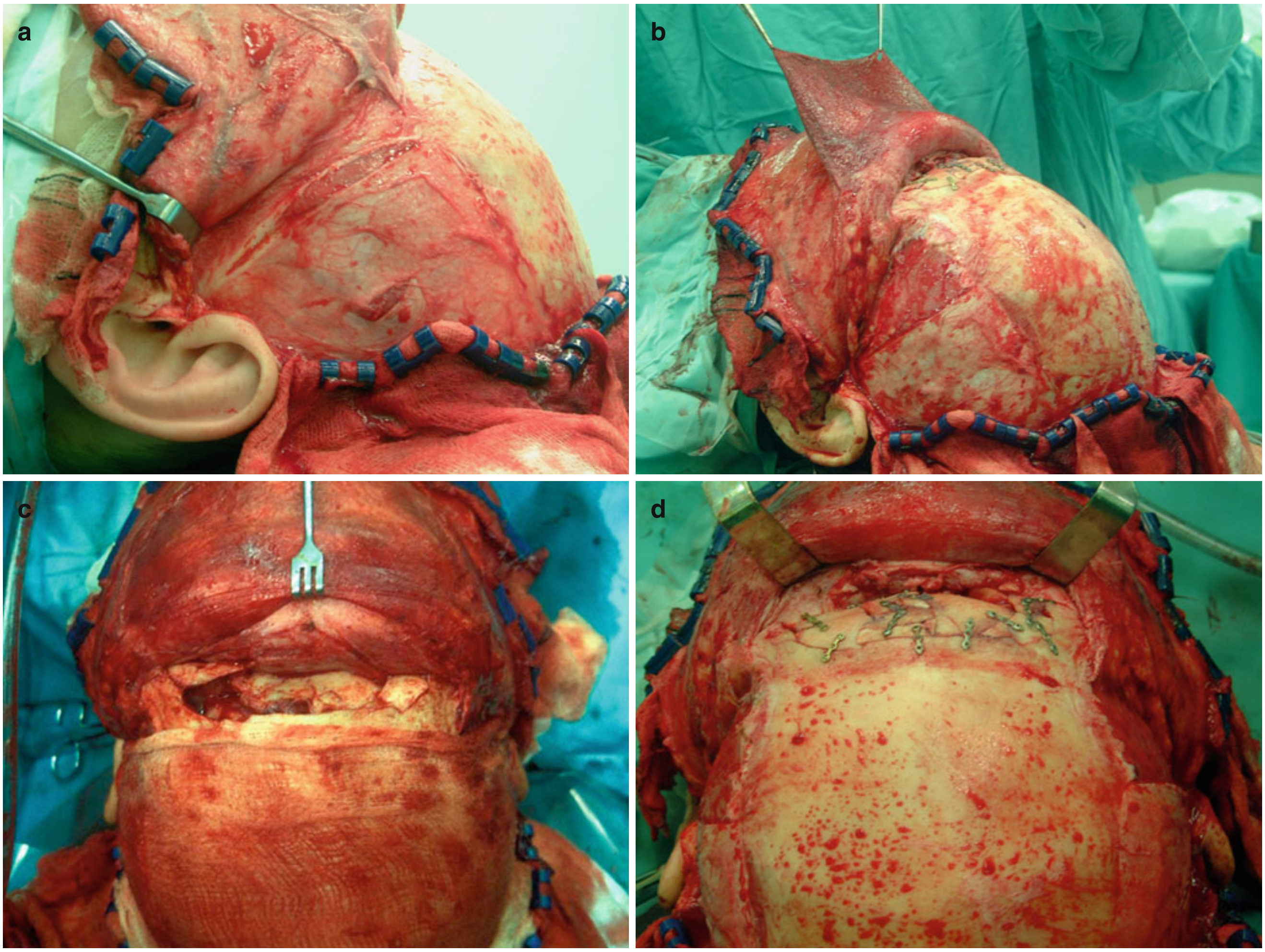

Fig. 13.32 (**a**–**d**) Coronal flap for repair of extensive frontal sinus fractures

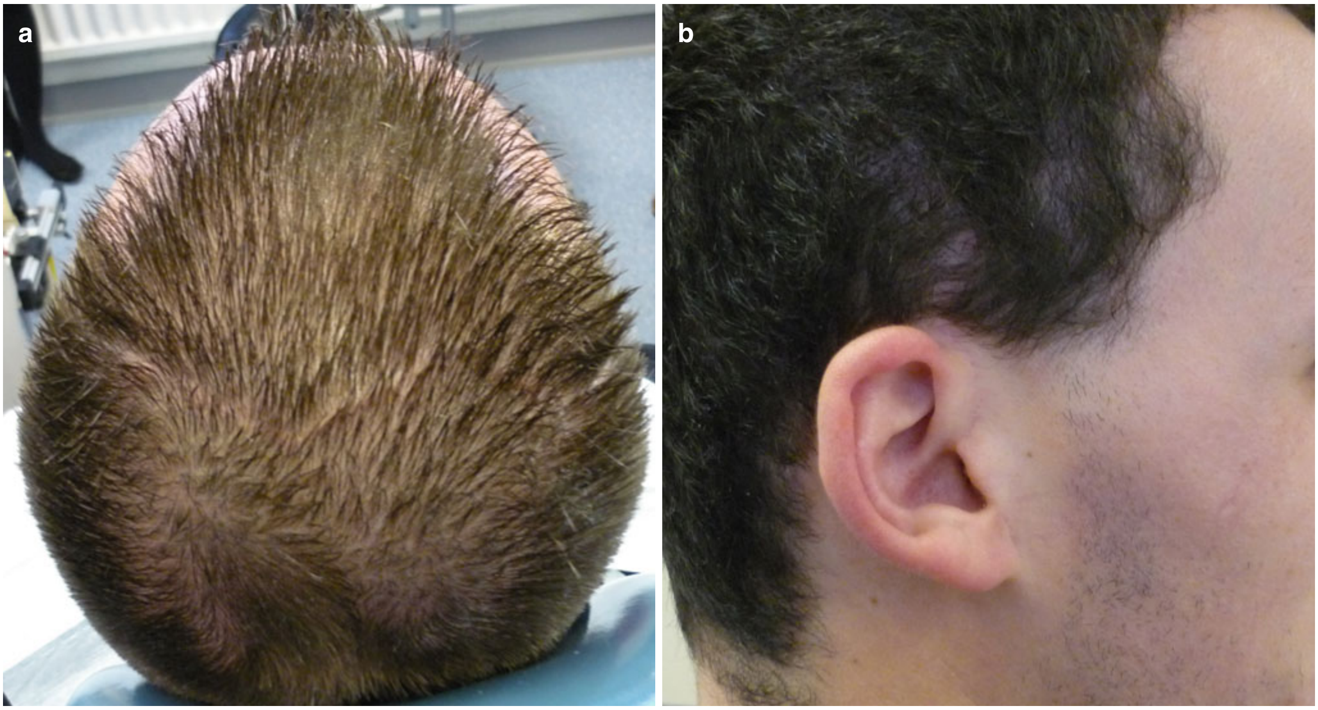

Fig. 13.33 (**a**, **b**) A carefully closed coronal flap should heal well with little obvious scarring

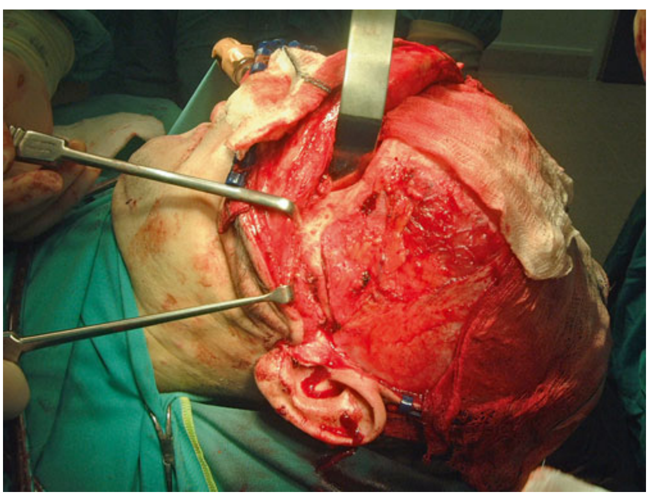

Fig. 13.34 Once raised, protect the tissues with damp gauze. These can dry quickly under theatre conditions

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Soft Tissue Injuries

14

Michael Perry, Sandra E. McAllister, and Simon Holmes

The term "soft tissues" is a nonspecific term, which can be interpreted to mean different things. In the context of this book, "soft tissues" refers to all the non-bony structures, including fat, muscle, nerves or vessels. An important element in management is to remember it is more than just the skin. This is important not only in the repair of soft tissue injuries, but also in the planning of follow-up and aftercare in all trauma.

Any wound that breaches the dermis will result in a permanent scar. How extensive this scarring is depends on a number of factors related to the trauma itself, the patient's biology, treatment received and aftercare. Final outcomes are therefore partly outside our control. However, outcomes can still be greatly influenced by careful surgical technique and gentle handling of the soft tissues. Optimal management of soft tissue injuries is therefore essential. Thorough wound toilet, judicious debridement and meticulous tissue handling are all required to achieve the best possible aesthetic and functional outcomes. Even if the skin has remained intact following an impact, subsequent neglect or mismanagement of the injured site can still result in significant deformity or disability.

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The vascularity, and consequently general health and quality of the "soft tissue envelope," is a key element in gaining a satisfactory outcome in the management of fractures. Its management must be carefully considered when planning repair or secondary reconstruction of both fractures as well as soft tissues injuries.

Fig. 14.1 Early cauliflower ear deformity following blunt trauma and subperichondrial haematoma. Early aspiration or incision and drainage may have prevented this

The very rich blood supply of the head and neck helps to defend this site against infection and promote healing. Despite high intraoral bacterial counts, infected wounds within the mouth are surprisingly uncommon. Saliva and exudates from around the gingiva contain antibodies and various growth factors, which facilitate rapid wound healing and prevent infection. This is why some animals lick their wounds. However, skin does not have these protective mechanisms and infection may arise not only from external sources, but also from naturally occurring commensal organisms. This can be promoted when there is devitalised tissue in the wound, within which the bacteria can proliferate. Penetrating injuries also need particular attention. Bacteria can be driven deep into the tissues and are then difficult to eradicate.

> The term "soft tissue envelope" means more than just the skin. Muscle, fat and nerves are all important components, contributing to the overall quality of the tissues. No matter how carefully the underlying bones have been repaired, poor management of any soft tissue injury will result in scarred, denervated and poorly vascularised tissues, all of which adversely affect outcomes.

14.1 Wound Healing and Different Types of Wounds

Several stages ("phases") of wound healing have been described (see Table 14.1). These involve complex interactions between the epidermis, dermis and extracellular matrix, involving angiogenic factors and plasma proteins. This is delicately coordinated by a number of cytokines and growth factors. The initial stimulus to wound healing following trauma is thrombus formation. Cells within the clot (notably platelets) trigger an inflammatory response by releasing vasodilators and chemoattractants. This is then followed by a proliferative phase, where fibroblasts migrate into the wound and begin to lay down collagen. Thereafter, the scar is remodelled in a process that continues slowly over a period of months to years.

During the early stages of healing, the scar is red and the surrounding tissues may be firm and swollen. Under normal conditions, this redness and swelling may be expected to improve over time, leading to a pale, soft scar. However, some patients may develop hypertrophic or keloid scarring. A hypertrophic scar is a raised scar that remains within the boundaries of the original wound. A keloid scar extends beyond the original wound and may become very extensive. A good example of this is the huge amount of keloid scarring that can occur following a simple cosmetic ear piercing. These can be very difficult to manage and tend to recur. When cutaneous incisions are planned, patients should therefore be asked if they have a history of these types of excessive scarring and counselled regarding the possibility of developing prominent scars.

Table 14.1 Phases of wound healing

Inflammatory phase
This begins at the time of injury, and lasts for 2–3 days. Injured vessels constrict with haemostasis. A platelet plug forms, loosely uniting the skin edges. Activation of the coagulation and complement cascades lead to deposition of fibrin and chemoattraction of inflammatory cells. Neutrophils predominate in the first 24 h after injury. These are important in phagocytosis of dead tissue and control of infection. Vasodilation soon follows with increased capillary permeability. Monocytes enter the wound and transform into macrophages. These predominate at 2–3 days. Monocytes continue to phagocytose dead or foreign tissue, and secrete growth factors (e.g., platelet-derived growth factor [PGDF] and transforming growth factor-β [TGF-β])
If the wound has been closed directly with sutures, the strain is taken by the suture material and wound strength at this time depends on the material used for closure. Any infection will delay progression to the next phase of wound healing
Proliferative (granulation) phase
This begins 2–3 days after injury, and lasts 2–4 weeks. Macrophages in the wound continue to produce growth factors. Fibroblasts migrate along fibrin threads and are activated by growth factors such as PDGF and TGF-β. These produce an extracellular matrix of collagen, fibronectin, and proteoglycans. Growth factors released by macrophages stimulate endothelial cells to produce new blood vessels (angiogenesis). This combination of immature vessels, fibrin and collagen fibres is called granulation tissue
Wounds will heal if neutrophils are deficient, but the presence of macrophages appears to be essential. The fibrin matrix initially forms a weak scaffold for healing. Keratinocytes at the wound edges undergo change and migrate along the surface of the matrix to re-epithelialise the wound
Remodelling (maturation) phase
Collagen produced in the proliferative phase is initially laid down in a disorganised fashion. This is gradually replaced with new collagen (mainly type I), which is more organised and has a cross-linked pattern. This slowly increases wound strength. Myofibroblasts cause the wound to contract. Fibroblasts and macrophages gradually leave the wound and reorganisation of the vessels leads to decreased vascularity of the scar
This phase may persist for 12–18 months. At best, 70–80 % of the original tissue tensile strength may be regained, but scar tissue generally does not regain the strength of unwounded tissue

Fig. 14.2 Keloid scars following cosmetic ear piercings (**a**, **b**)

14.1.1 Classification of Wounds

Wounds may be classified as "clean" or "compromised" (see Table 14.2). Clean wounds which do not become infected have the greatest chance of healing with minimal scar formation.

14.1.2 Haematomas (Haematomata)

Most haematomas resolve over time, although occasionally they can fibrose, leaving a firm nodule in the soft tissues. Very rarely, haematomas in muscles can calcify, resulting in a disfiguring hard lump palpable under the skin. This is known as myositis ossificans or heterotopic calcification. Regular massage helps prevent this by breaking up the clot and any scar tissue that has formed.

Auricular and septal hematomas deserve special consideration because of their potential for subperichondral collection and necrosis of the underlying cartilage. These require incision and drainage. Septal hematoma is described elsewhere. Auricular hematoma usually arises following blunt trauma. Following incision and drainage, a compressive dressing is worn for several days. Failure to drain an auricular haematoma may result in a "cauliflower" ear, as the haematoma undergoes fibrosis and contraction.

Table 14.2 Classification of wounds

Clean
Sharp incision
Low energy trauma
Uncontaminated
Less than 6 h old
Compromised
Ragged edge
High-energy trauma
Crushed tissue
Tissue loss
Burns
Contaminated
More than 12 h old

Fig. 14.3 Large haematoma following a fall. There are no associated fractures. This required incision and drainage

Fig. 14.4 Delayed presentation of subperichondrial haematoma. The ear had been stitched, but no pressure dressing applied. There has been further bleeding and infection

14.1.3 Initial Assessment and Management

It is important to take sufficient time to make a careful assessment of any soft tissue injury. Knowledge of anatomy is essential to help assess for tissue loss or underlying injuries (e.g., fractures or nerve injury). Initial appearances can often be quite deceptive. This can be either due to the presence of clot (which holds the wound together and disguises its extent), or because retraction of skin flaps create the appearance of tissue loss.

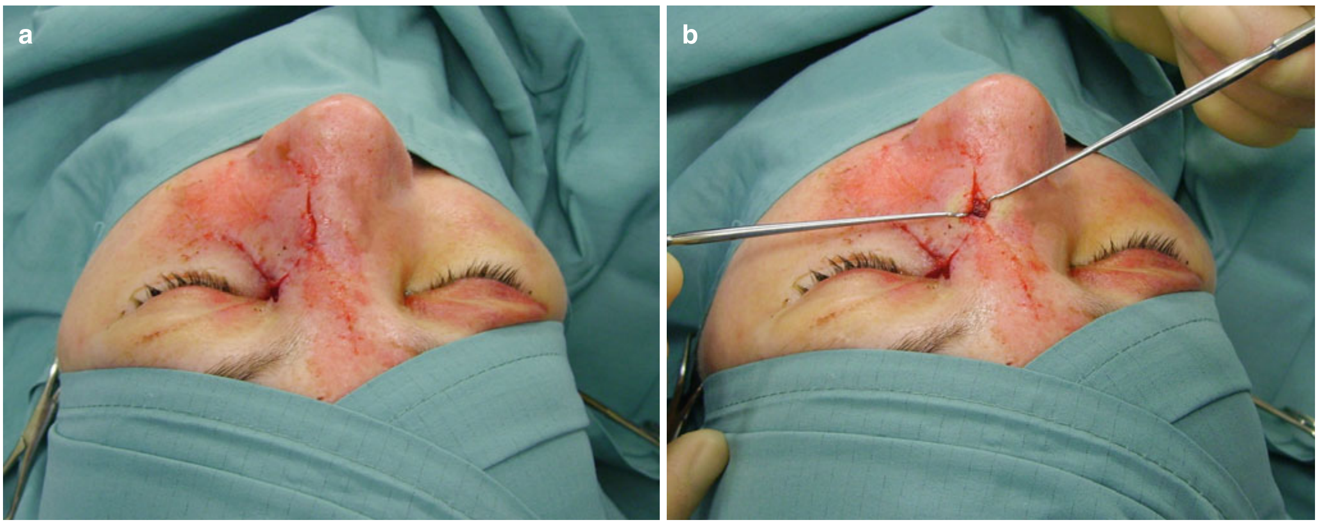

Fig. 14.5 Some wounds can be quite deceptive. What initially appears as a trivial wound is in fact very extensive (**a**, **b**)

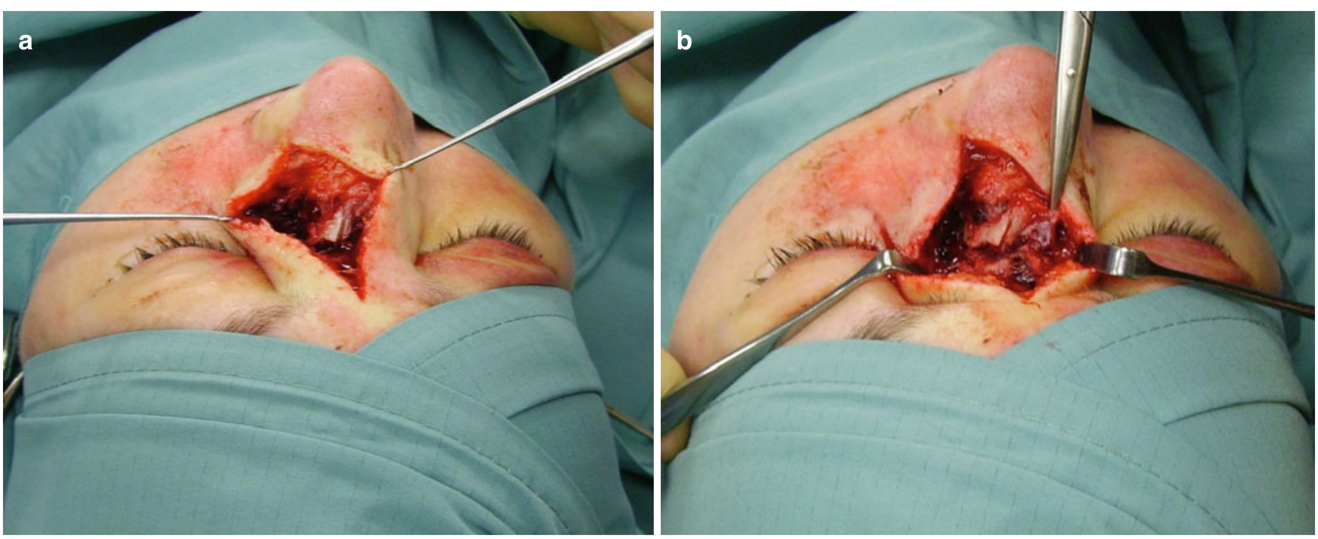

Fig. 14.6 The laceration extends down to bone and there are underlying comminuted nasal fractures (**a**, **b**)

Before exploring any wounds consider the possibility that this may produce further bleeding. If necessary have the appropriate equipment to hand to control haemorrhage. Be especially careful with scalp and neck wounds, and in children.

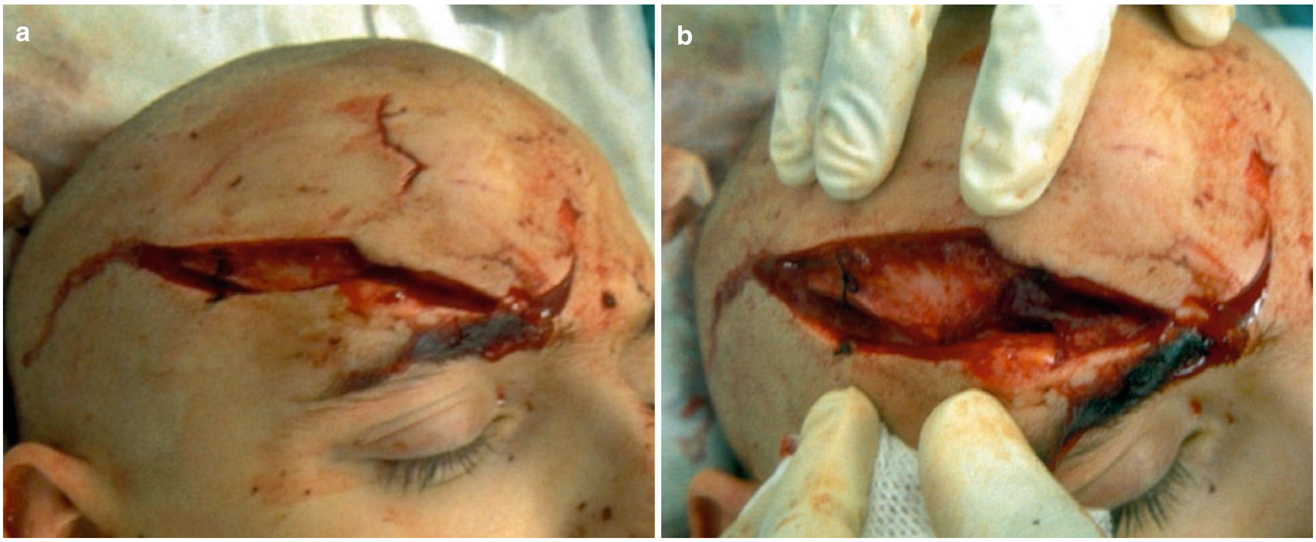

Fig. 14.7 Examination of a scalp laceration. These are almost always down to periosteum or bone (**a**, **b**)

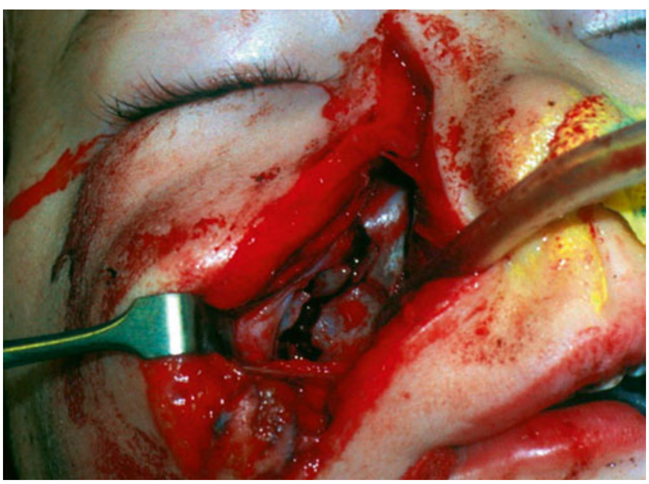

Fig. 14.8 Underlying maxillary fractures following kick by a horse

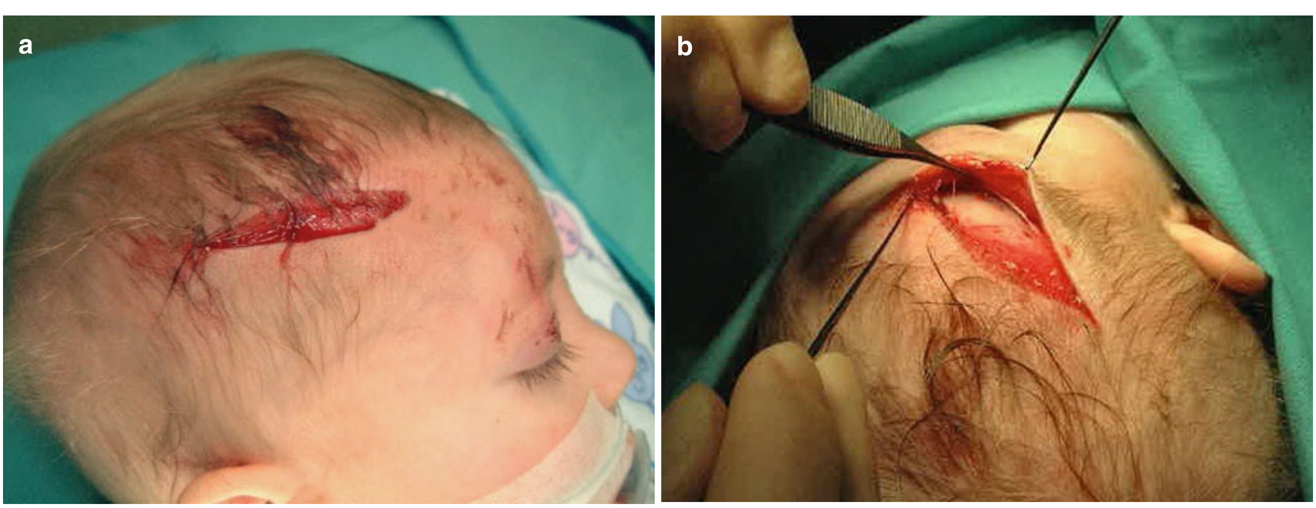

Fig. 14.9 Scalp wounds are usually deep and often down to bone. These need careful assessment. Consider the mechanism of injury and the possibility of fractures. In children blood loss can be significant (**a**, **b**)

A simple checklist is useful to ensure associated injuries are not overlooked and to plan management (see Table 14.3).

Table 14.3 Initial wound/soft tissue assessment and management

ATLS™ principles. Involve other specialists as necessary
Control haemorrhage: apply pressure with a clean pad of gauze
Any foreign bodies or wound contamination (possible dirt tattooing)?
Any injuries to underlying structures?
Is tissue lost, or just displaced?
Is haematoma formation likely (especially with closed injuries)?
Is any imaging required?
What is the anticipated extent of scarring?
Consider the mechanism of injury (incised v crushed tissues)
Can the wound be managed properly under local anaesthetic?
Document carefully: ideally, photograph the wound
Consider tetanus prophylaxis and antibiotic treatment
If there will be a delay before definitive management, gently clean and loosely close, or dress the wound appropriately
Warn all patients about scarring and subsequent deformity

Facial injuries are clearly very distracting; however, patients may also have other serious injuries which may not be immediately apparent. Therefore, approach all patients with caution, taking a careful history and performing a systematic examination. Always begin with Advanced Trauma Life Support (ATLS™) principles in mind (notably blood loss), taking into account the mechanism of injury (blunt versus sharp or penetrating trauma). With high-energy injuries (e.g., ballistic injuries), not only will fractures be comminuted but the soft tissues will also be extensively damaged. Some areas of tissue may be critically ischaemic and these may go on to necrose over the next few days, resulting in wound breakdown. Regular reassessment is therefore necessary. Depending on the complexity of the overall injury, a short delay in repair may allow dead tissue to "declare" itself, thereby helping in debridement.

Consider and examine for injuries to the underlying structures (dentition, bones, globe, lacrimal gland, eyelid levators, canthus, parotid duct, facial nerve, sensory nerves).

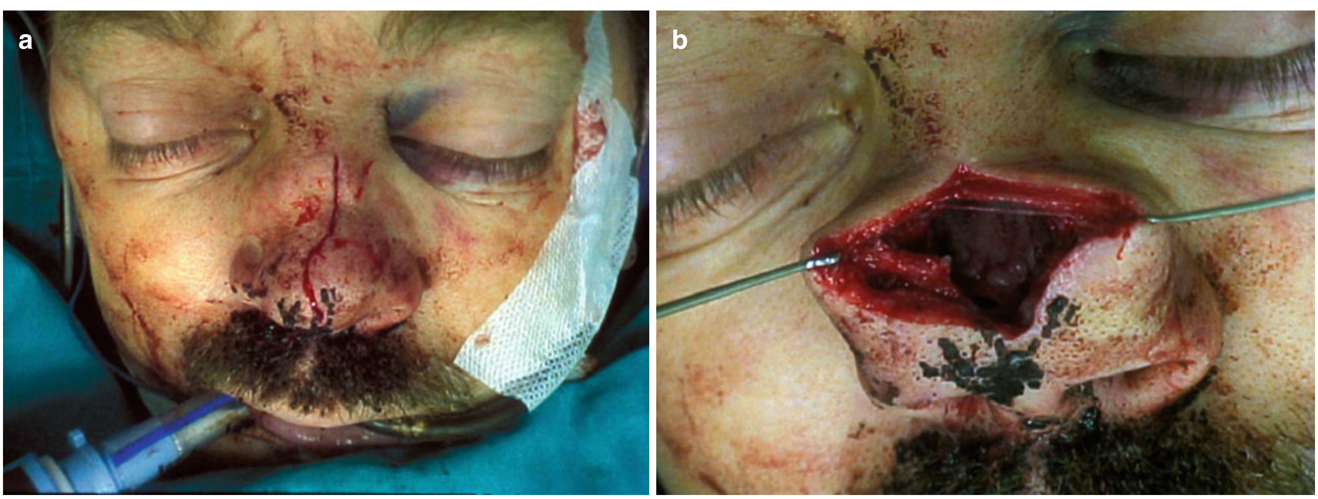

Fig. 14.10 Significantly depressed nasal fracture involving septum and bones (**a**, **b**)

Twisted, or kinked flaps should be gently realigned and supported as soon as possible. Failure to do so may make the difference between an ischaemic, but recoverable flap and an infarcted one.

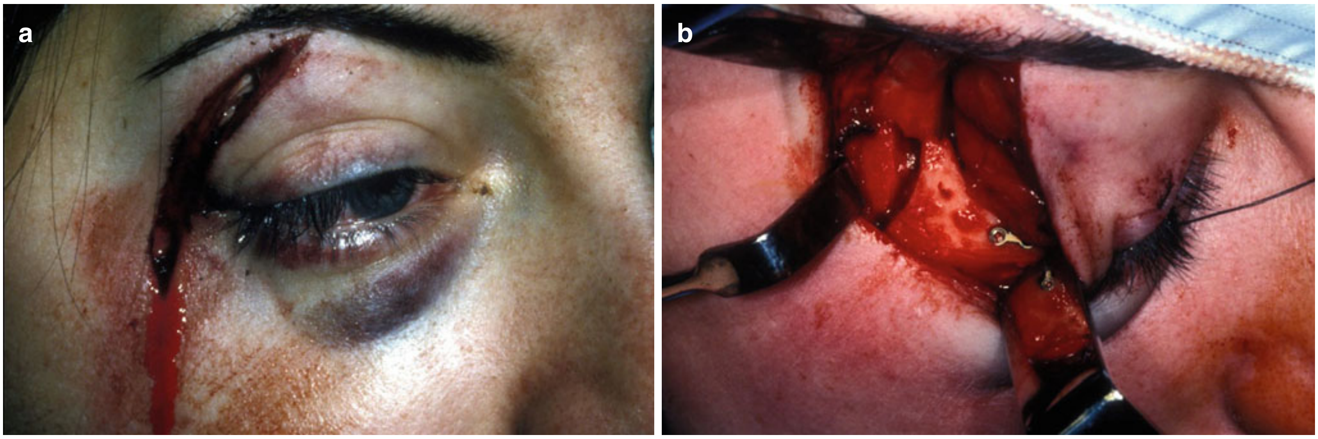

Fig. 14.11 Patient hit by a brick, resulting in comminuted fractures to the orbital rim and lateral orbital wall (**a**, **b**)

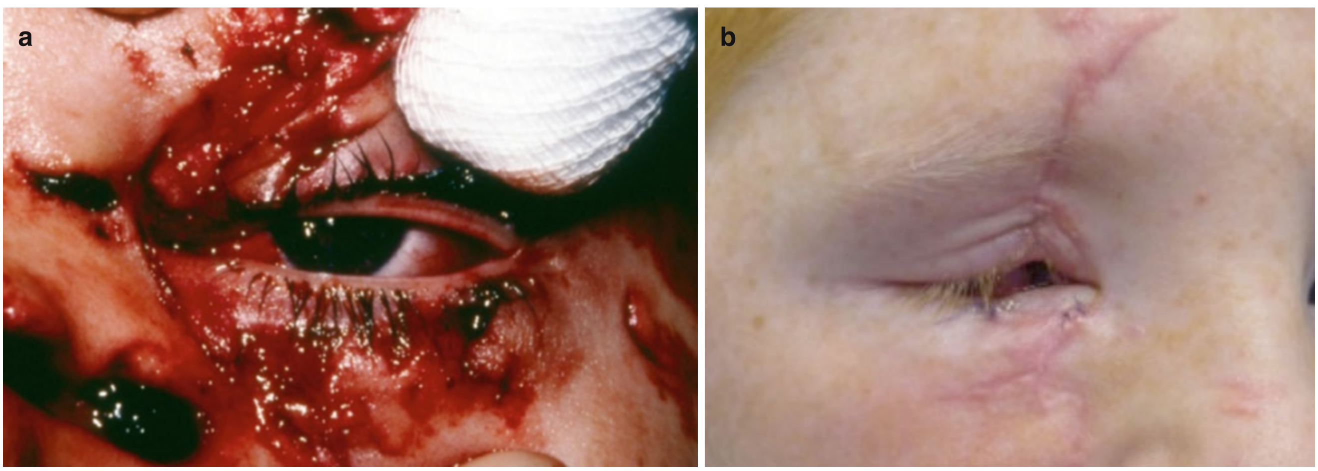

Fig. 14.12 Eyelid lacerations need careful assessment and repair. Scarring can result in significant functional impairment (**a**, **b**)

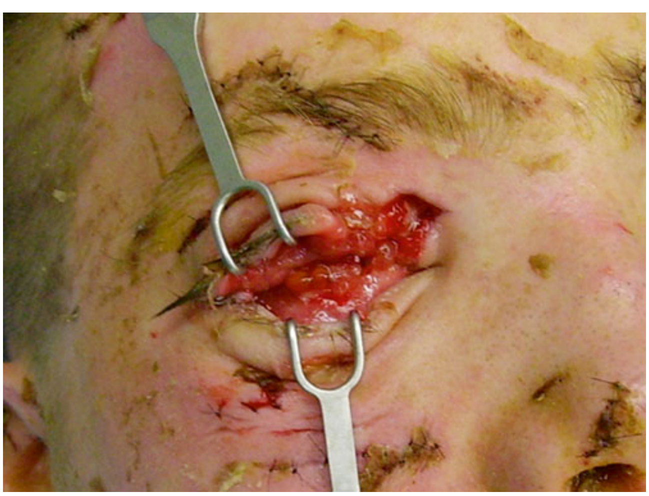

Fig. 14.13 Ruptured globe following high-speed vehicle collision resulting in multiple injuries

Always have a high index of suspicion for the presence of foreign bodies. Identifying these often requires imaging. Plain films are often required, although computed tomography (CT) may be needed to identify deeper foreign bodies and to help locate them precisely. In the presence of metallic foreign bodies, magnetic resonance imaging (MRI) is contraindicated. MRI is more useful in identifying nonmetallic foreign bodies, such as plastic, but some materials may still be very difficult to see (notably vegetation such as twigs, etc.). Do not forget to ascertain if any teeth have been lost—a chest and neck x-ray may be necessary.

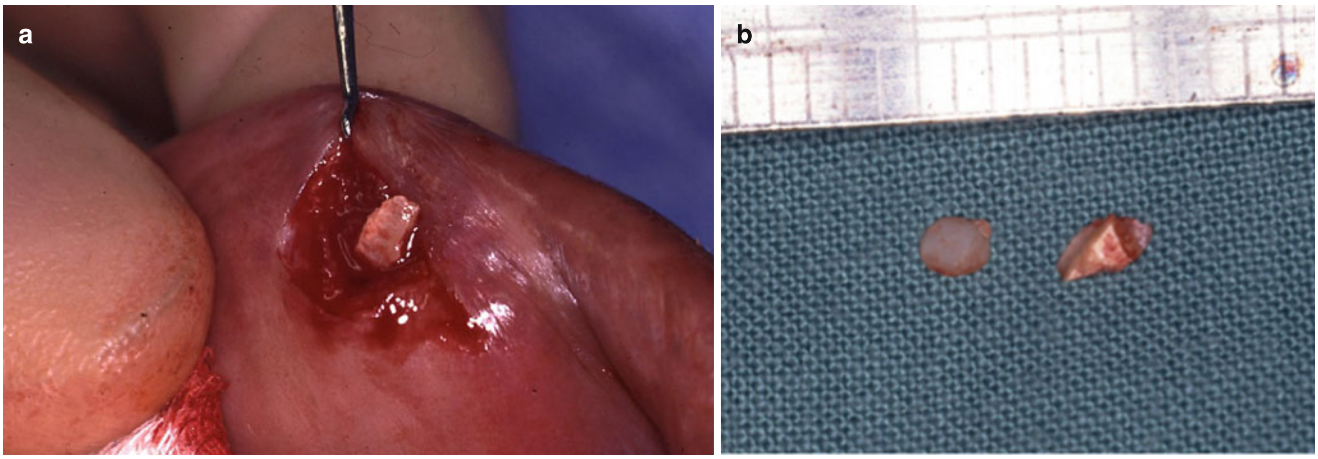

Fig. 14.14 Retained tooth fragments in the lower lip following a fall (**a**, **b**)

Fig. 14.15 Delayed presentation of painful lip following a fall. There was an obvious foreign body (FB) (**a**, **b**)

Fig. 14.16 Removal of tooth

Fig. 14.17 Multiple glass fragments (*red circles*) following ejection from a car (through the windscreen)

Fig. 14.18 An obvious case of penetrating injury with glass. What is important is not how much glass is seen, but how much is in the patient and has it fragmented?

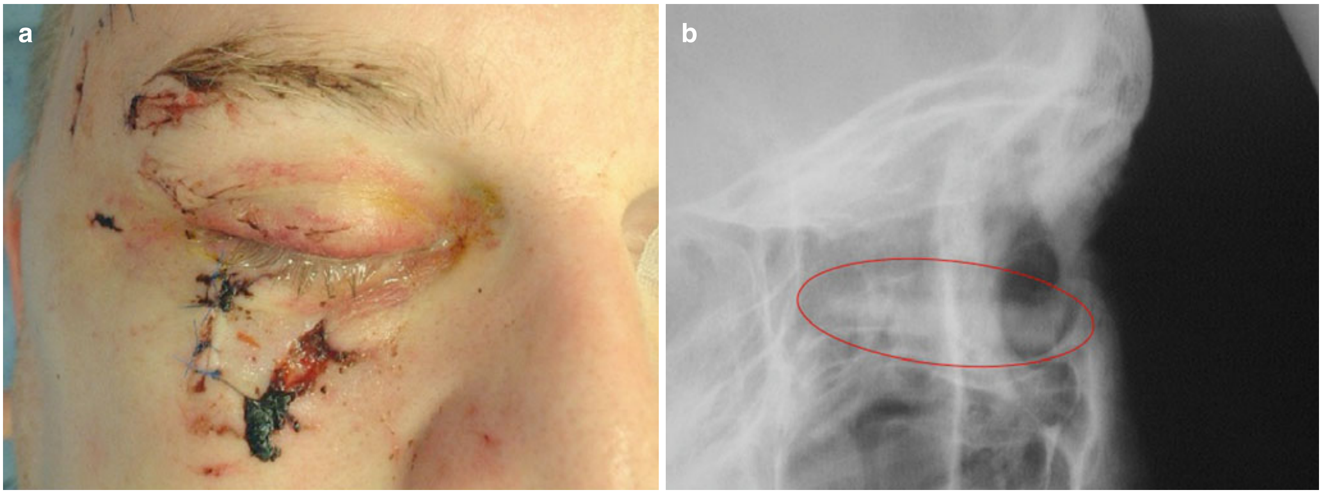

Fig. 14.19 Patient presenting having been hit in face with beer glass. Glass seen on plain film passing along the floor of orbit, below the globe. Fortunately the globe was intact (**a**, **b**). The *red circle* highlights the glass fragment

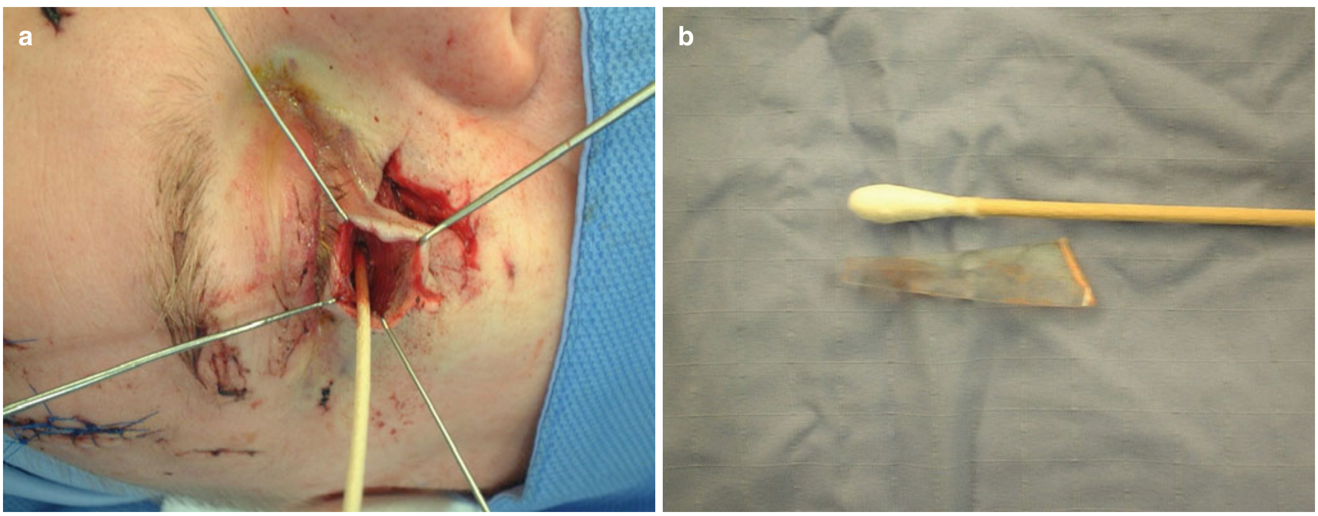

Fig. 14.20 Exploration and retrieval of glass (**a**, **b**)

Fig. 14.21 Wound closed

With projectiles (e.g., airgun pellets, bullets) the final resting position of the pellet may be distant from the point of entry. From a maxillofacial perspective, imaging of the neck may be required, but it is important to remember that projectiles may travel through or lodge in the chest and abdominal cavity. Consider this in any hypotensive patient following penetrating injury. Seek advice if necessary.

Fig. 14.22 Air gun pellet injury (**a**, **b**)

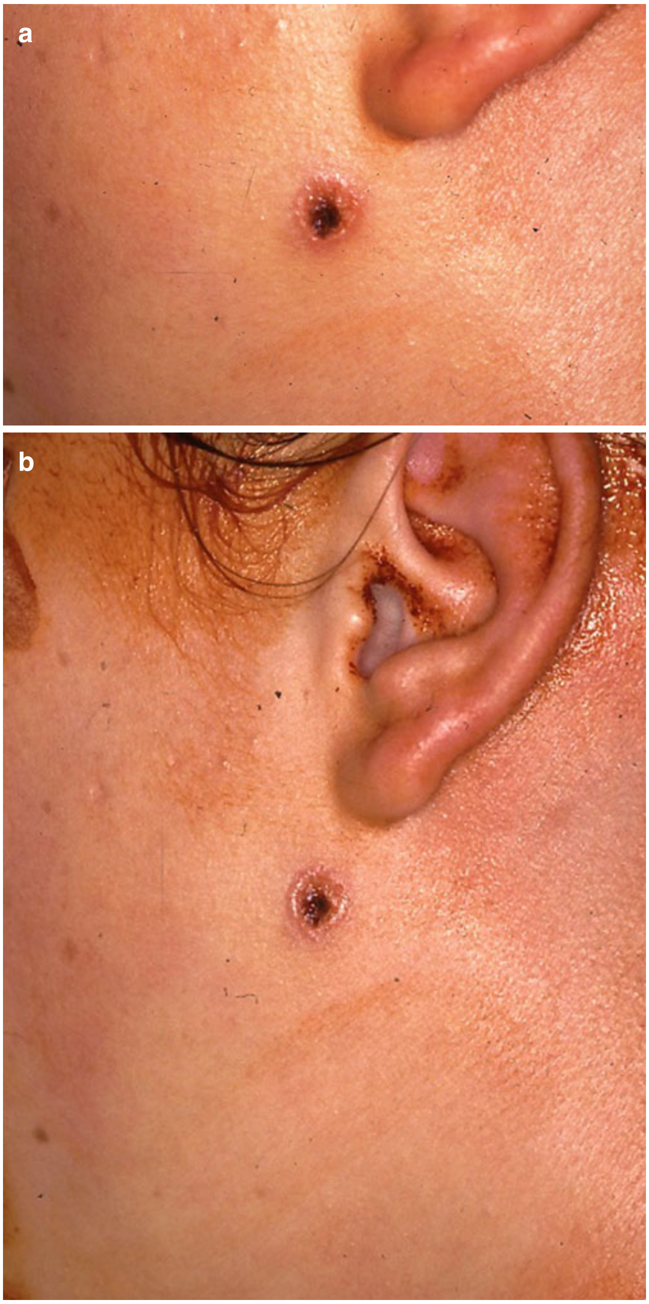

Fig. 14.23 This patient initially attended thinking she had been stung by a wasp (**a**, **b**)

Fig. 14.24 X-ray confirmation of an air gun pellet

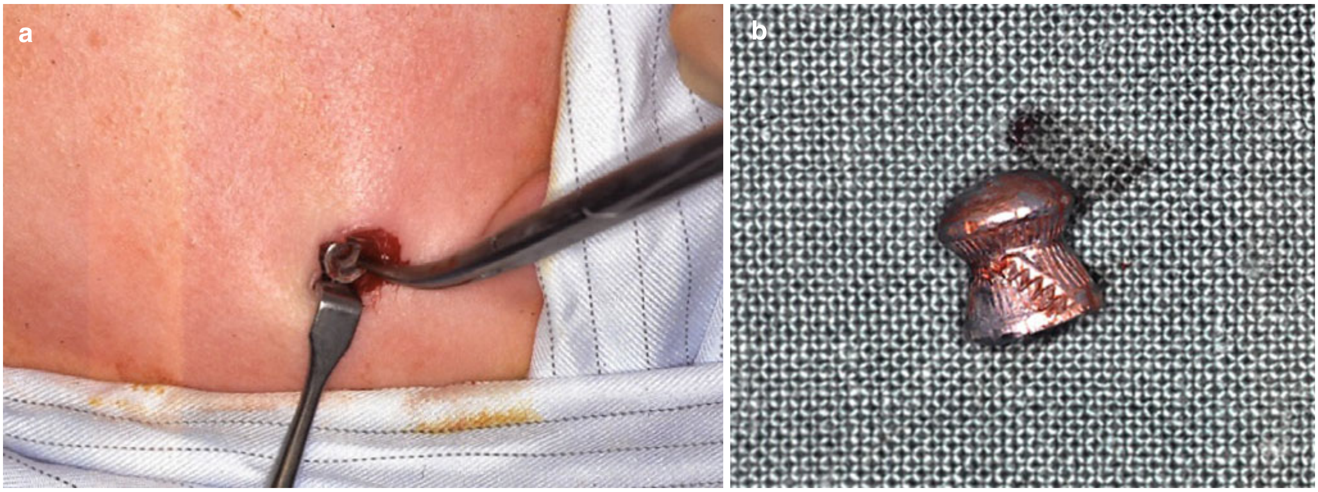

Fig. 14.25 Retrieval and specimen (**a**, **b**)

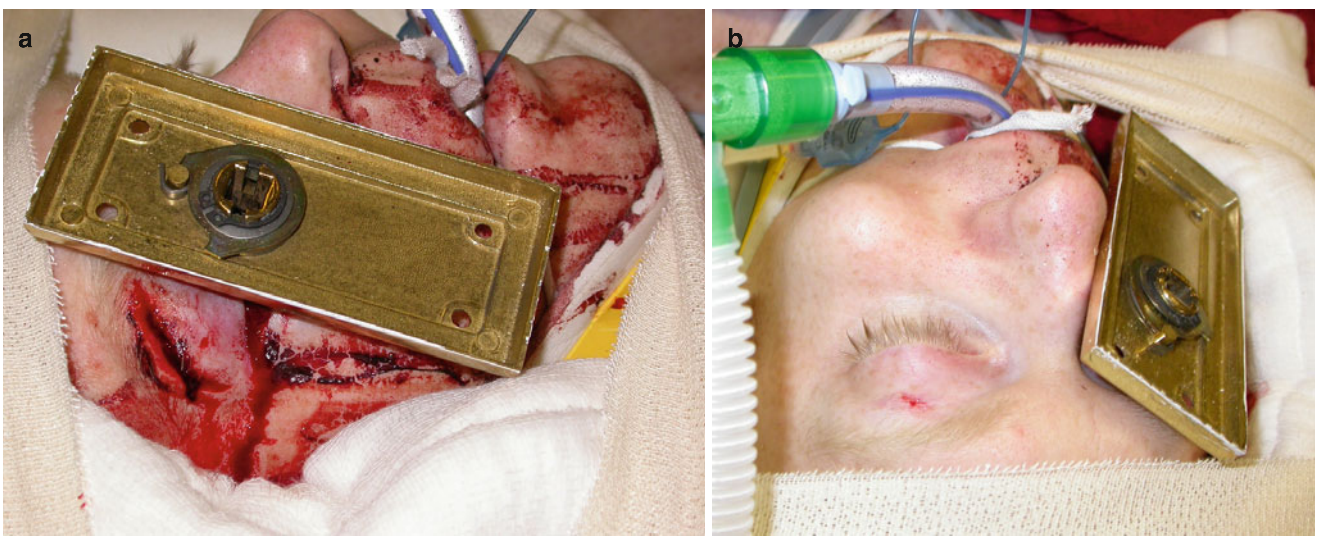

Fig. 14.26 An unusual and more obvious foreign body following a fall (**a**, **b**)

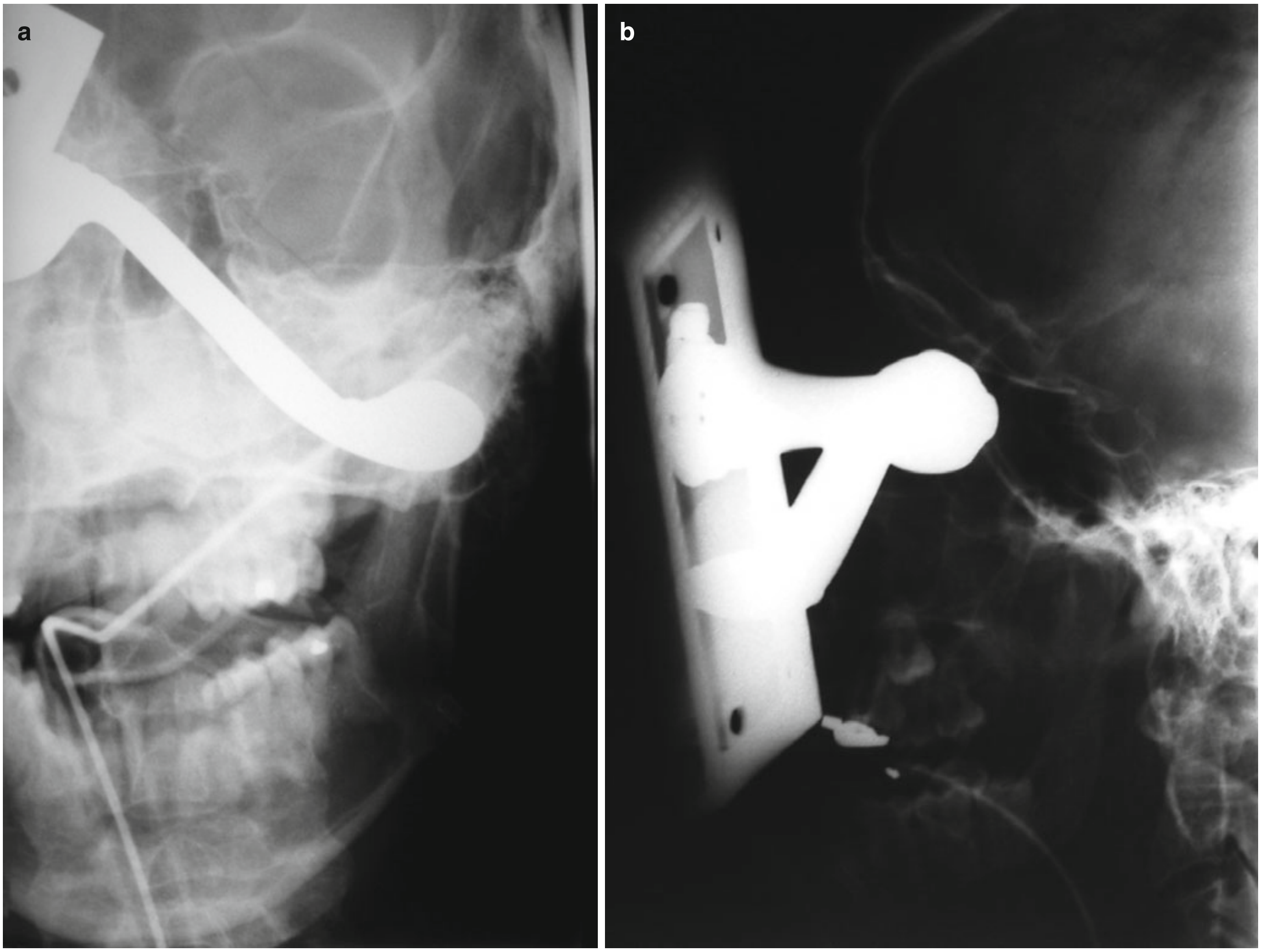

Fig. 14.27 Its position and size are determined radiographically (also using CT) (**a**, **b**)

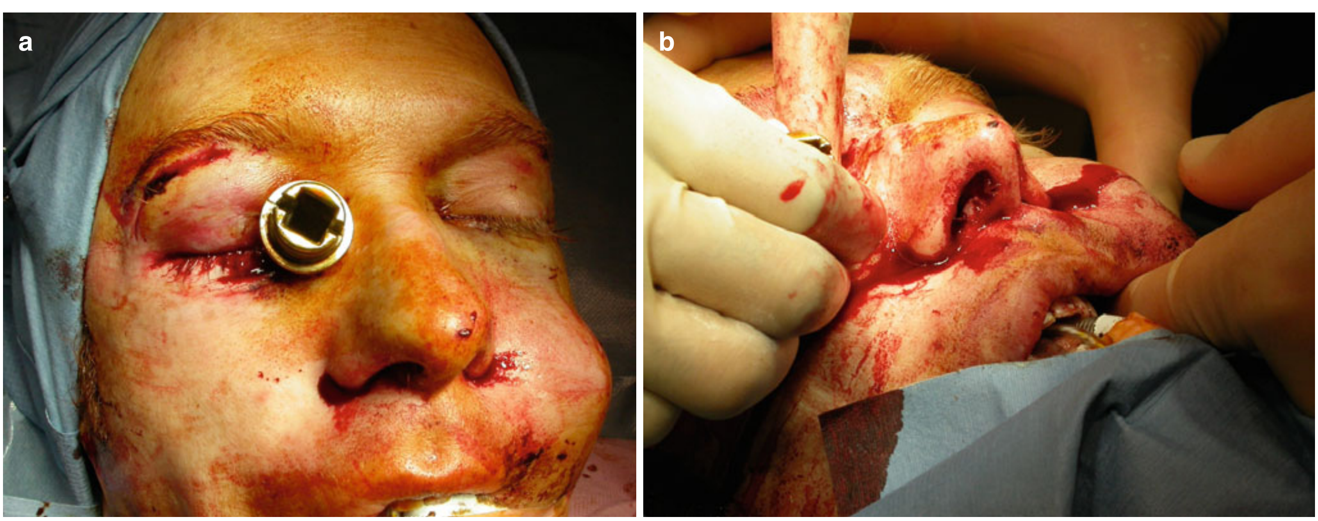

Fig. 14.28 The outer cover was removed and an examination under anaesthesia carried out (note bulge in left cheek from tip of handle) (**a**, **b**)

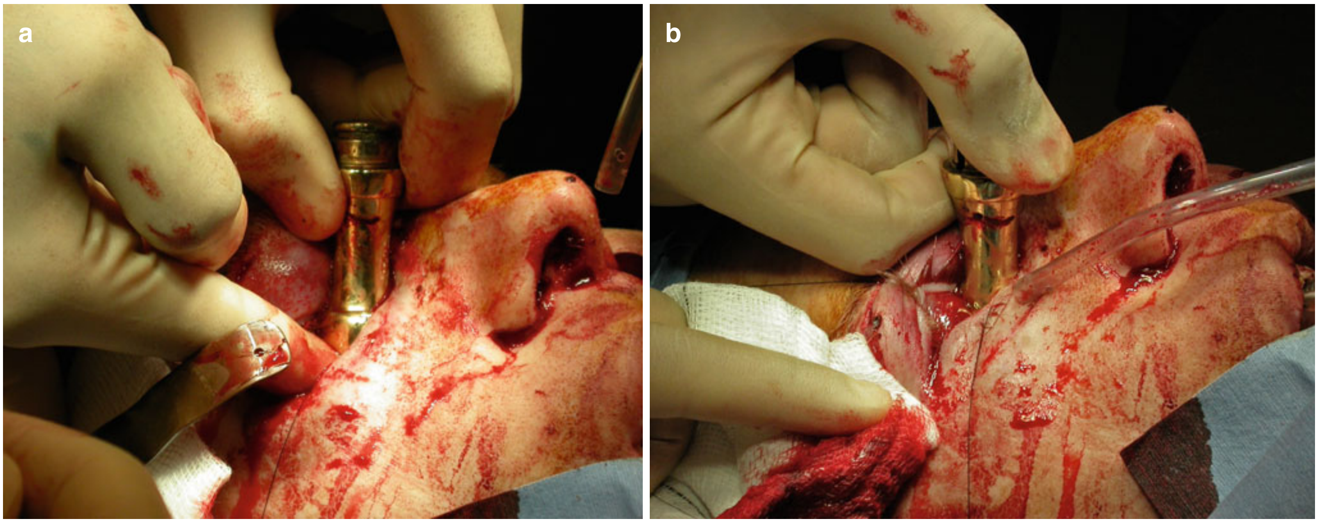

Fig. 14.29 The handle is carefully manipulated out the mouth and socket (**a**, **b**)

Fig. 14.30 Following wound closure

Twisted or kinked flaps of tissue should be gently realigned and supported in their correct position as soon as possible. Loosely suture these flaps, or use adhesive paper strips to hold them in place until definitive repair. Failure to do so may make the difference between an ischaemic, but salvageable flap and an infarcted one. Due to the face's excellent blood supply, partially avulsed skin, even if attached by a small pedicle, may still have a good enough blood supply to enable it to heal if repositioned and secured. Anecdotally a glycerine trinitrate (GTN) patch cut to shape and applied to the flap appears to improve perfusion.

If any delay in definitively closing the wound is anticipated, gaping wounds should be gently cleaned, loosely closed (using sutures or adhesive paper strips) and dressed. If closure is not possible, irrigate the wound and cover it with an appropriate dressing.

Copious but gentle irrigation is the best way to clean a wound. Although a number of antiseptics are available, some are reported to harm tissues and can delay healing. Sterile saline solution or water are not harmful to wounds and are recommended by many authorities. If antiseptics are used to irrigate wounds, remember to protect the patient's eyes.

Fig. 14.31 Partial avulsion of lower lip. This was repositioned and tacked in place while awaiting repair. Failure to do so may have resulted in tissue loss (**a**–**c**)

Fig. 14.32 This patient had sustained multiple injuries and had to wear a hard collar for several days. Unfortunately no one looked at the ear. There was extensive necrosis with significant loss of tissue (**a**, **b**). This was possibly avoidable

14.1.4 Debridement and Trimming of Wounds

Following wound closure, any remaining dead tissue can provide a focus for infection, or lead to wound breakdown. Debridement before closure may therefore be required. However, wide excision is to be avoided as this will result in an extensive defect which will be difficult to close. This is particularly important around certain key sites, such as the eyelids, nose and lips, where distortion of tissues will result in significant functional and cosmetic problems. If an extensive area of soft tissue needs to be debrided, involve experienced reconstructive colleagues at an early stage.

Tattooing can occur when grit and debris are not completely removed from a wound. This subsequently goes on to heal with visible particles under the skin surface. Foreign material must therefore be removed by meticulous wound cleaning and careful debridement. It is essential to remove all foreign material and this may require prolonged but gentle scrubbing of the wound (scrubbing in itself is additional trauma). Regional nerve blocks or general anaesthesia may

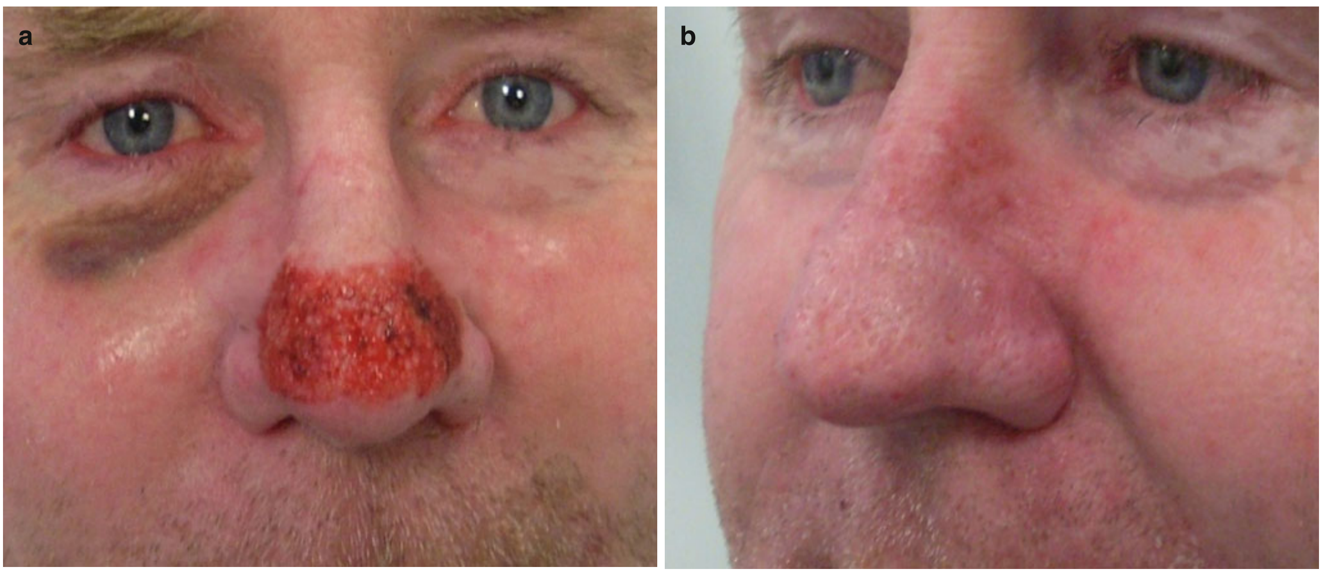

Fig. 14.33 A contaminated nasal abrasion following a fall. This has been carefully cleaned and dressed (**a**). Appearances at 2 months (**b**)

be necessary. Take care not to scrub too aggressively. Overenthusiastic scrubbing can cause further trauma to the wound and extend any zones of ischaemia, resulting in devitalisation of tissue. Small fibres from the scrubbing brush can also be left in the wound, resulting in further foci for infection. If scrubbing is required use a small toothbrush and apply gentle pressure. Be patient—removal of all dirt may take some time.

Good lighting and equipment are needed to manage these wounds properly. The use of magnification (operating loupes) can also be very helpful when removing small particles of dirt. For small pieces of grit, the tip of a pointed scalpel may be used. If the wound edges are ragged, or if there is any obvious devitalised tissue, careful trimming back to healthy bleeding tissue may be required. If wound contamination is extensive, clean and debride as far as possible then dress the wound and arrange for another wound inspection after 24–48 h, ideally with wound closure during the same procedure.

Examine and document any tissue loss, ascertain the patient's tetanus status, and take a wound swab for microbiological culture. Prescribe broad-spectrum antibiotics and tetanus prophylaxis, according to local protocols.

> The general aim of wound cleansing is to remove any organic and inorganic debris from the wound before applying a dressing. Debris can delay the healing process and result in infection. Abrasions need careful cleaning to remove all traces of grit and other foreign bodies.

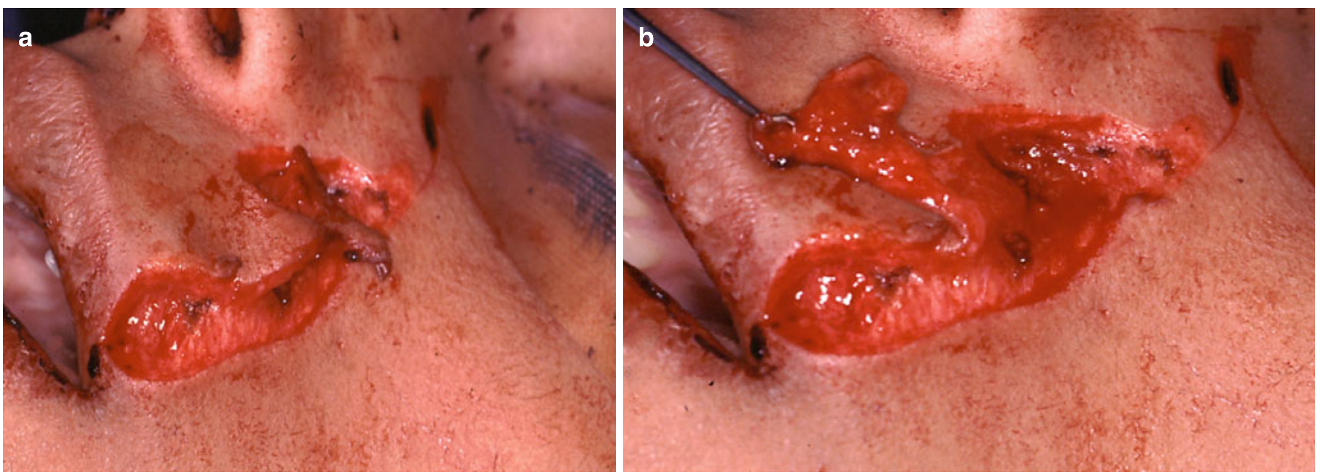

Fig. 14.34 Trimming of irregular skin edges can make wound closure easier (**a**, **b**)

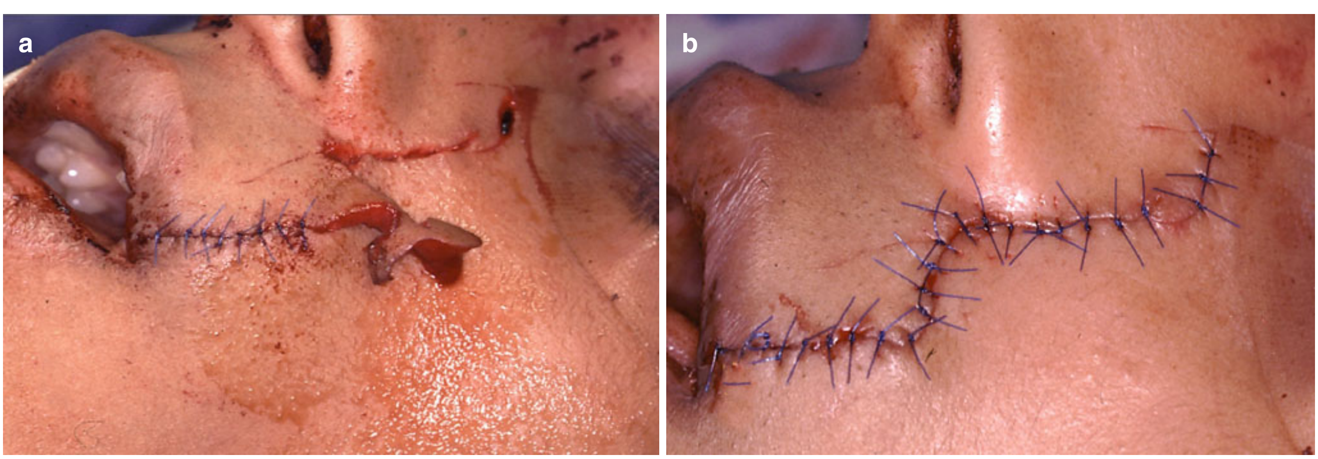

Fig. 14.35 The gaping wound has been closed in layers and surplus skin excised (**a**, **b**)

14.2 Bites and Scratches

Whether animal or human in origin, these injuries must be considered as potentially serious injuries and managed expeditiously. Both can rapidly become infected if they are not treated properly. Dog bites can range from simple puncture wounds, to irregular tears, to missing chunks of tissue. The canines (the largest teeth) can penetrate deeply, taking bacteria deep into the wound (Fig. 14.36). Depending on the patient (and the dog) underlying fractures have also been reported. Unlike other sites on the body, bites and scratches on the face can often be closed primarily. This is due to the excellent blood supply and relatively good healing potential of the face, compared to elsewhere. However, these injuries must be thoroughly cleaned and irrigated prior to suturing and should be monitored closely for signs of infection. All crushed and devitalised tissue should be carefully removed. Abscesses can develop in the deeper tissues. More unusual bites (e.g., farmyard animals, snakes, spiders) require specialist knowledge due to the risks of exotic infections or venoms.

Fig. 14.36

14.3 Intraoral Wounds

These tend to occur following blunt trauma, during which the tissues are either avulsed from points of attachment, or are lacerated by underlying fractures or nearby teeth. Intraoral wounds need to be assessed carefully as they can often contain debris and can quickly become infected. Small wounds, including those of the tongue, can often be left and will heal uneventfully. Larger ones need repair.

> Be careful with penetrating palatal injuries in children. The typical history is a fall while running with a pencil or pen in the mouth. Although the palatal wound itself is usually small, carotid injury and delayed stroke have been reported.

Fig. 14.37 Partial degloving injury to the anterior mandible. These often occur following a fall onto the face during which the lip is partially avulsed. They are often highly contaminated

Fig. 14.38 A full-thickness tear to the upper lip with associated dentoalveolar injuries (**a**). This was repair in layers (mucosa/muscle/skin) (**b**)

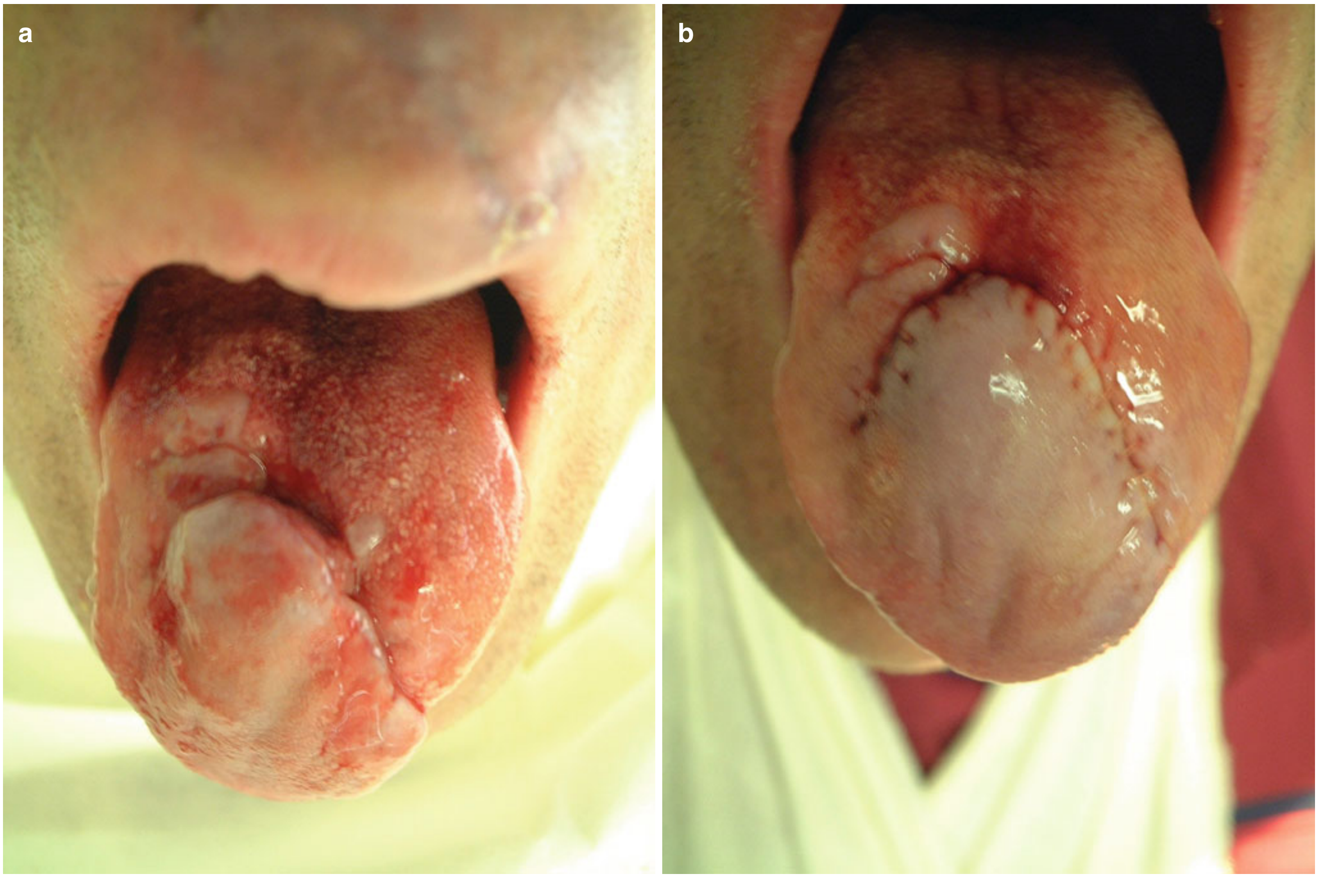

Fig. 14.39 A deep tongue laceration following an epileptic fit (**a**). Repaired in layers with a resorbable suture (**b**)

14.4 Repair of Soft Tissue Lacerations

Repair or closure of a wound may be classified as "Primary," "Delayed Primary," or by "Secondary Intention" (Table 14.4).

Table 14.4 Wound closure

Primary closure
The wound is closed as soon as possible using glue, sutures, clips or adhesive paper strips (e.g., Steri-Strips). The wound margins are opposed with no spaces between the edges
Delayed primary closure
The wound is left open for several days, before being directly closed. This is useful if tissue is of questionable vitality. The wound is cleaned, debrided of all obviously dead tissue and then dressed. This allows time for dubious areas to declare their vitality. A "second look" is then performed, usually 24–48 h later. Any further necessary debridement is undertaken, prior to definitive closure
Secondary intention
If there is infection or tissue loss, the skin edges may be left open, allowing the wound to granulate from its base. Healing time may be lengthy, and considerable scarring and deformity will probably occur

14.4.1 Primary Closure

Clean wounds should ideally be closed as soon as possible with meticulous care, precise haemostasis and accurate repositioning of the tissues. When suturing an irregular wound, look carefully for recognisable landmarks—matching these will greatly facilitate accurate apposition of the remainder of the wound. If the wound edges are ragged, trimming the edges may convert an "untidy" wound margin to a neat edge which can then be closed giving a superior aesthetic result. However, trimming should be reserved for dead or obviously damaged tissues, and should be kept to a minimum. Wide excision of tissue from the face may lead to difficulties in achieving a good functional and aesthetic closure of the defect, particularly near the eyes, nose and mouth. There

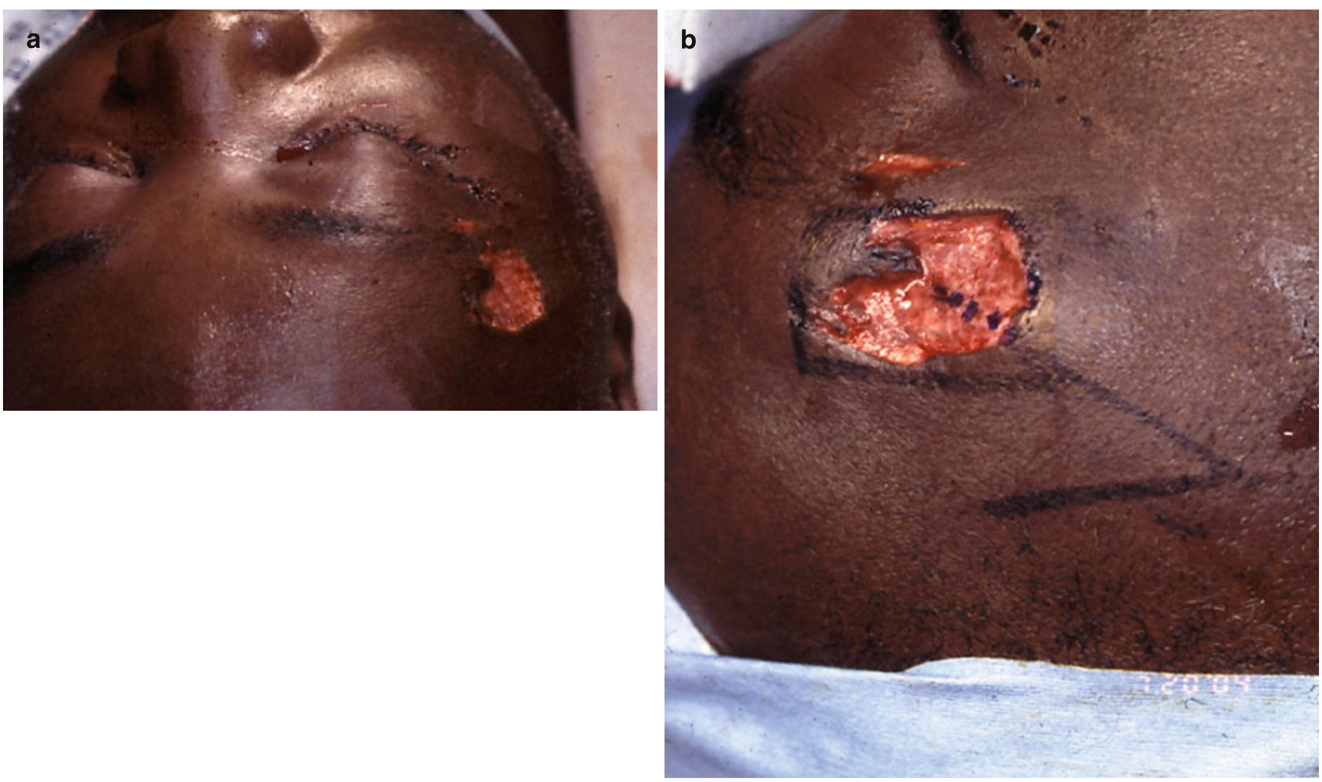

Fig. 14.40 Immediate repair of wound following tissue loss. Patient was struck by an object. Following minimal trimming of skin edges, a "rhomboid" flap was planned (**a**, **b**)

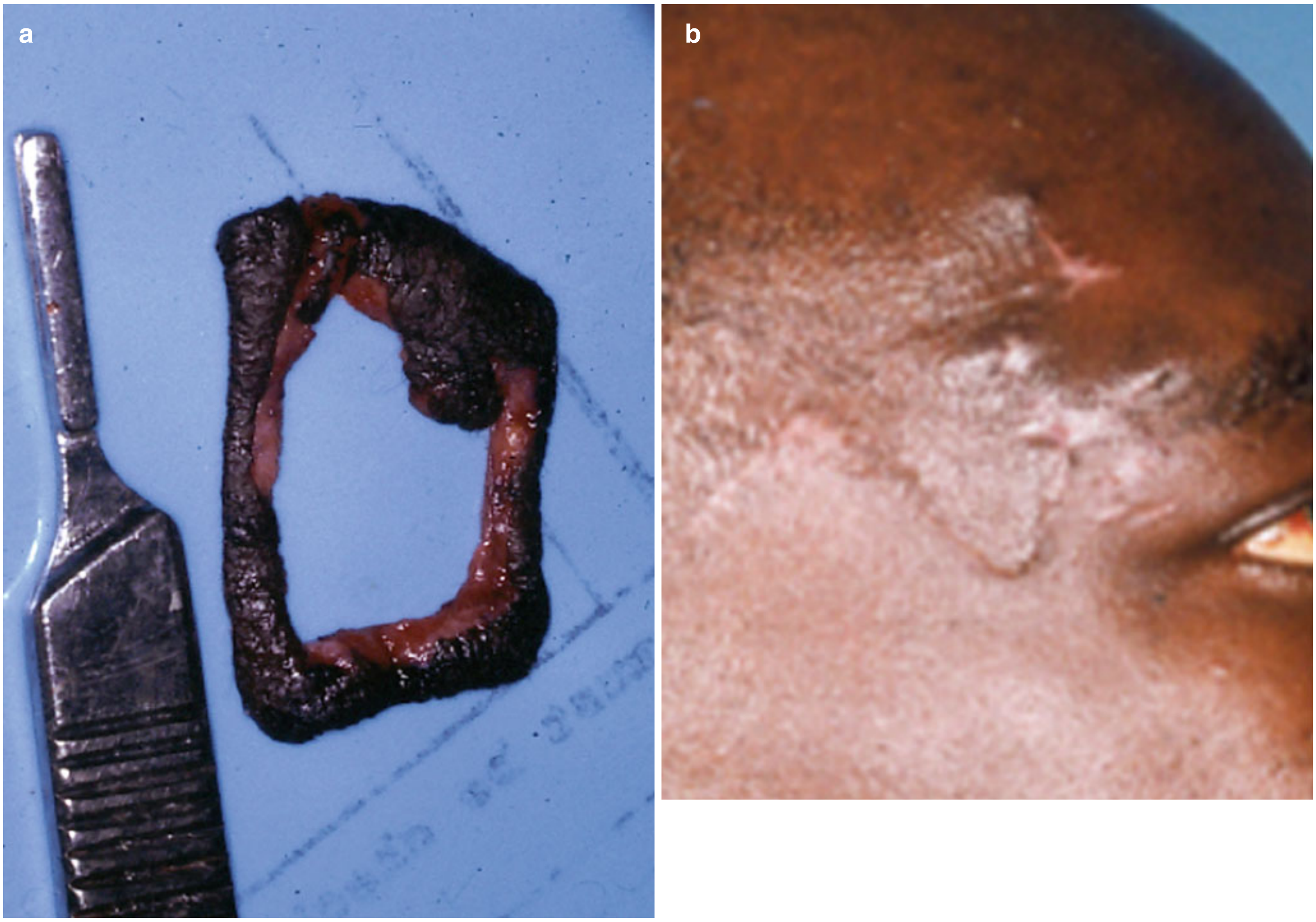

Fig. 14.41 Skin excised (**a**) and appearances at 2 months (**b**)

should be no tension across the wound. In cases where tension is a problem, undermining of the skin, local flap closure, or skin grafts may be used. If doubt exists about viability, tissue is often left in place and inspected later.

In the vast majority of cases, primary repair of simple, isolated wounds is undertaken as soon as possible. Good light and instruments are essential, and it may be prudent to do this in the operating theatre, rather than struggling in the emergency department or outpatient clinic. Ideally, wound closure should be performed within 12 h of injury. Provided the tissues are well vascularised, even wounds colonised with bacteria can be closed primarily using appropriate antisepsis and antibiotic treatment. This is seen particularly with intraoral wounds, which are all heavily contaminated with oral bacteria.

14.4.2 Suturing

Suturing is the commonest method of wound closure, especially with full-thickness or deep lacerations. These are usually closed "in layers." The underlying tissues are precisely aligned to eliminate any "dead space" beneath the surface. Closing the skin only and leaving a potential space or cavity can predispose to abscess formation, and compromise wound healing. When closing the skin the aim is to produce a neatly opposed and everted wound edge. A small amount of eversion is reported to compensate for depression of the scar during wound contraction. Inversion of the wound edges produces an inferior result and should be avoided. Do not tie the sutures too tightly—the correct tension is just short of that which causes blanching of the skin, i.e., local ischaemia. Bear in mind that postoperative swelling will effectively tighten the sutures in the days that follow. Therefore, try to allow for this when securing the sutures, otherwise tight sutures may cut into the tissues and increase the formation of suture marks (cross-hatching). These areas of ischaemic tissue are also at risk of infection and dehiscence.

It is essential to handle the tissues carefully (see Table 14.5).

Table 14.5 Tips in suturing

Take time to learn the techniques to produce neat and accurate wound opposition
Avoid pinching the skin edges with toothed forceps; rather, use a skin hook, or one side of the forceps as a hook to hold the wound edge steady whilst you place the suture
Note the curve of the needle and use a smooth wrist rotation to glide it smoothly through the tissues. Pull the suture material through gently. This is usually quite delicate
Sutures can be placed in an interrupted or continuous fashion: it may be argued that interrupted sutures give a superior aesthetic result, but continuous intradermal sutures can give a very acceptable aesthetic outcome when placed carefully
Remember to close in layers
Do not tie the knots too tight (see text)

Case 1

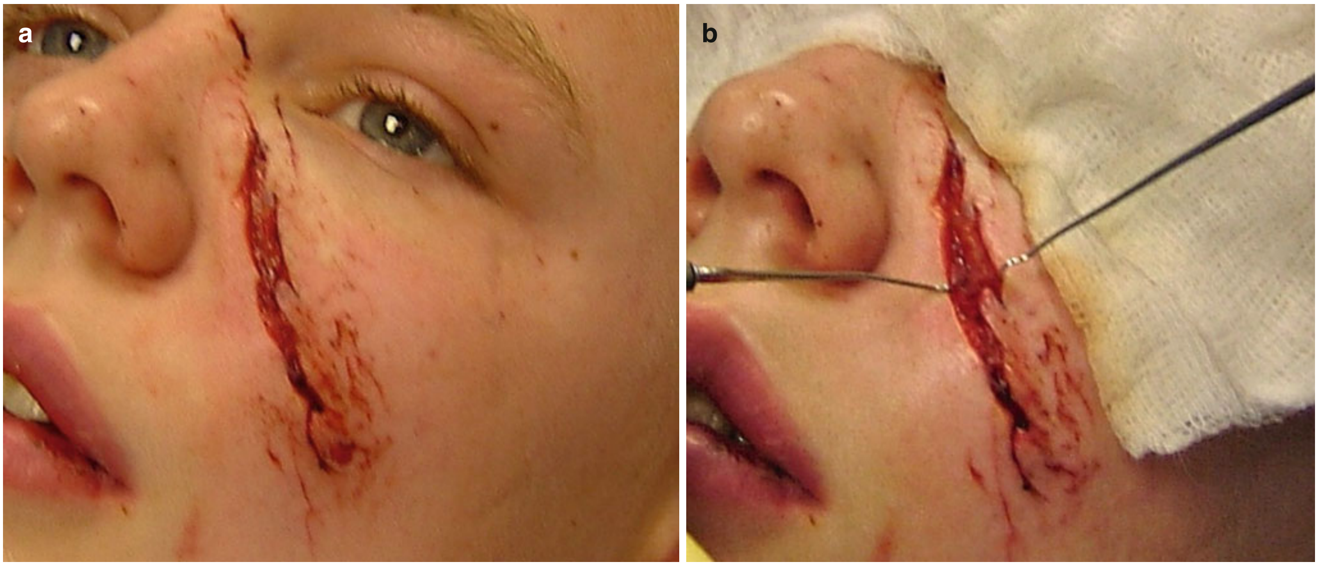

Fig. 14.42 Primary closure of an irregular wound following a dog bite (**a**). The wound is initially cleaned and explored (**b**)

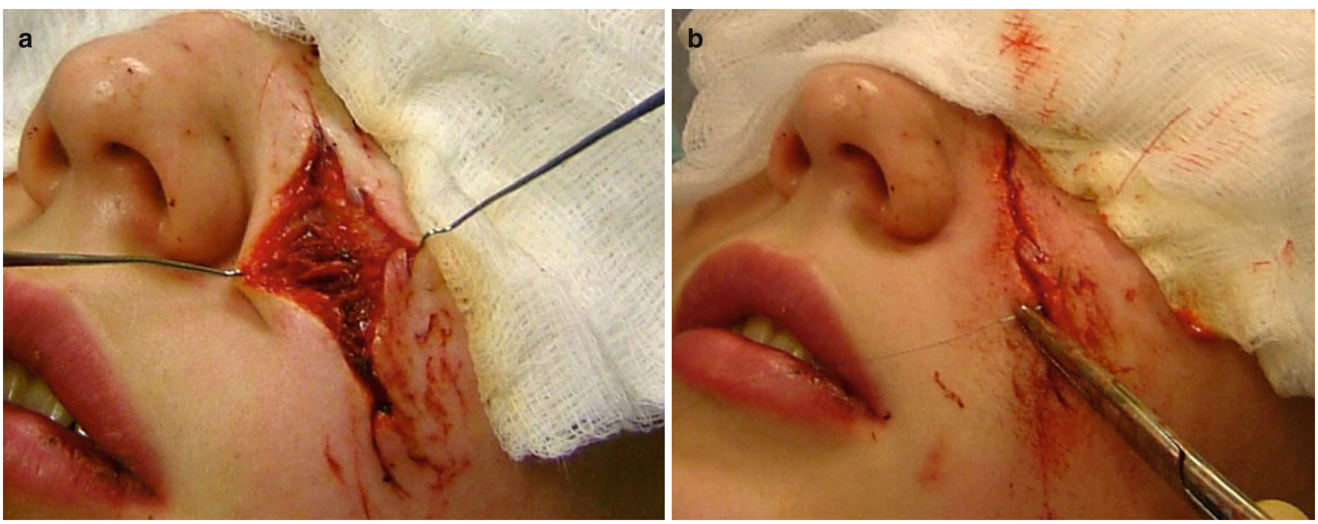

Fig. 14.43 Examination revealed a deep wound requiring closure in multiple layers (**a**, **b**)

Fig. 14.44 Interrupted skin sutures. Note multiple small abrasions which also required cleaning

Case 2

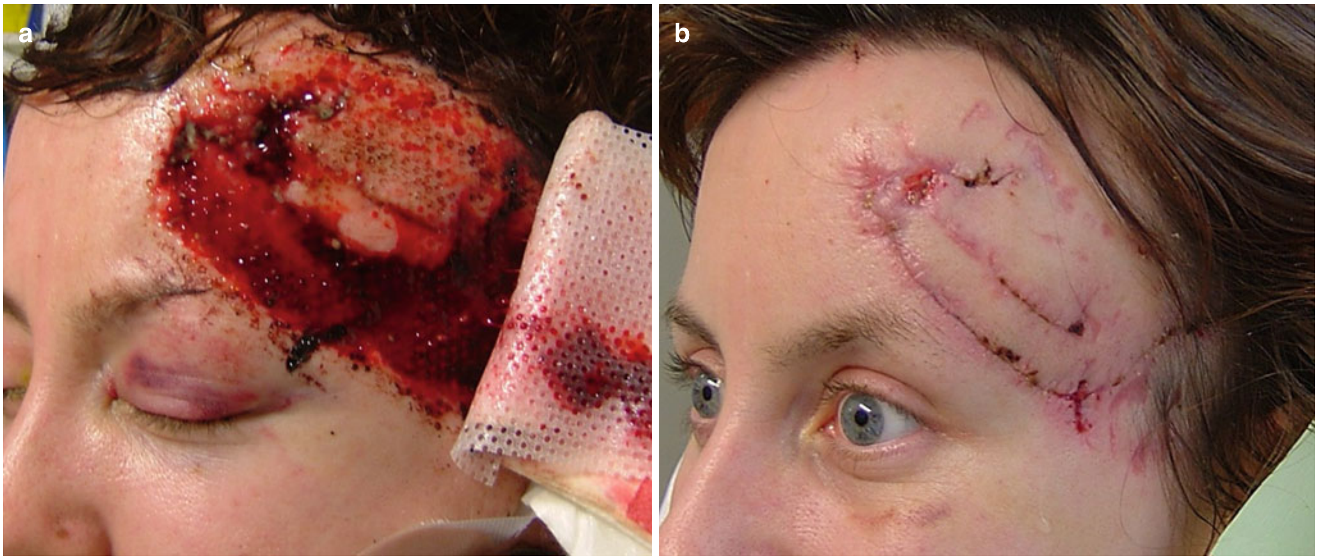

Fig. 14.45 Patient was struck by an object resulting in a "shelving type" laceration and injury to the upper branch of the facial nerve. Repair was undertaken under general anaesthesia (**a**, **b**)

Fig. 14.46 Appearances at 1 month (**a**) and 1 year (**b**)

14.4.3 Alternative Methods

Alternatives to sutures include metal clips, adhesive paper tapes and skin adhesives (e.g., cyanoacrylate glue). These can be applied quickly, but accurate alignment of skin edges can be difficult. Metal clips tend to be reserved for lacerations involving the scalp. Adhesive paper tapes and skin glues are especially useful in children and those who will not cooperate. Care is required in both patient and wound selection. Only superficial facial or hairless scalp wounds should be considered. The final cosmetic results are less predictable with these techniques compared to carefully placed sutures, as the unsupported deep tissues may gape. Although apparently simpler, gluing can still be quite tricky—take care not to allow glue to enter the patient's eyes, ears or mouth and be careful not to glue your glove to the patient. Although it can be removed, this can be very embarrassing (you will not be the first to do it).

Deeper wounds are closed in layers, usually with deep absorbable sutures, followed by skin closure. Well-placed deep sutures can often align the wound sufficiently such that the skin can be closed using only skin glue or just a few delicate sutures.

14.4.4 Choice of Suture

Many different suture materials are currently available. The choice depends on a number of factors, such as the characteristics of the wound (including whether the patient will tolerate suture removal), the period of time over which suture support is desirable (including whether the suture is to be removed or left to absorb), ease of use and the surgeon's preference.

Sutures can be classified according to their origin (natural or synthetic), although the majority of sutures now in common use are synthetic. More commonly sutures are now classified as absorbable or nonabsorbable.

Examples of absorbable sutures are polyglactin (Vicryl) and polyglycolic acid (Dexon). Nonabsorbable sutures include silk, nylon, and prolene.

Absorbable sutures tend to be used to close the deep tissues, or in areas where the aesthetic result is not the primary consideration. They gradually lose tensile strength as they are degraded. The rate of absorption depends on the suture calibre and the wound conditions. Unfortunately, with some larger sutures the rate of degradation may be so prolonged that persistence of the suture causes cross-hatching if used to close the skin. However, in children a very fine absorbable suture may be used. This avoids the stress of subsequent suture removal. Excellent results have been seen following lip repair with fine absorbable skin sutures supplemented with the application of cyanoacrylate and steri-strips to confer several days of support and water resistance. These very fine sutures disintegrate over a period of days, leaving no suture marks.

Cross-hatching of a scar occurs as a result of closing the wound under tension, or leaving sutures in situ for too long. Ischaemia of the deeper tissues damages the skin and stimulates excess collagen formation.

Nonabsorbable sutures need to be removed. This must be carefully timed to balance the needs of sufficient wound support against the risks of developing cross-hatching. Cross-hatching in scars is regrettably common. This is difficult to eradicate and may require revision, with further excision and primary closure. Sutures placed in the face are usually removed around 5 days after surgery, or even earlier in delicate tissues such as the eyelids. With neck lacerations, sutures are often retained for longer (7–10 days). Scalp sutures are similarly left for 7–10 days, or absorbable sutures are used in areas of hair-bearing skin.

Sutures may also be classified according to their structure. They can be divided into monofilament or braided. Monofilament sutures handle well, pass smoothly through the tissues and are often the suture of choice for skin. They produce minimal tissue reaction, and should be considered where there is a risk of infection. Braided sutures (e.g., silk),

have plaited strands which provide secure knots, but may trap material providing a focus for infection. Historically, silk was commonly used for suturing wounds in the mouth, as it was easy to handle, strong, and the ends were comfortable for the patient. However, Vicryl is now a popular choice, particularly since it resorbs and does not need to be removed. The choice of suture used in the mouth often depends on the preference of the surgeon.

Some of the sutures in common usage are shown in Table 14.6.

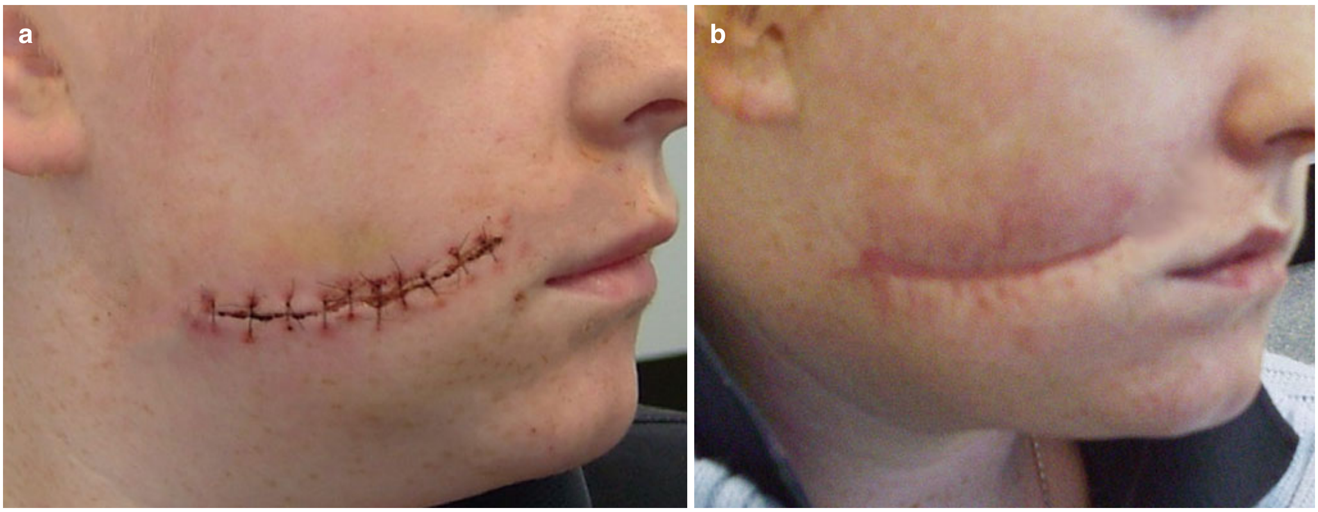

Fig. 14.47 Cross-hatching in a scar (**a**, **b**). The most likely cause is closure under tension. A subcuticular suture may have yielded a better result

Table 14.6 Suture properties

Suture	Material	Structure	Properties
Absorbable sutures[a]			
Catgut	Natural: purified animal intestine	Monofilament	Absorbed by proteolytic digestion, within 90 days Retains strength for 21 days
PDS	Synthetic: Polydioxanone	Monofilament	Absorbed by hydrolysis, in 182–238 days Strength retention up to 6 weeks
Dexon	Synthetic: Polyglycolic acid	Braided	Absorbed by hydrolysis. Similar duration and strength retention to Vicryl.
Vicryl	Synthetic: Polyglactin 910	Braided	Absorbed by hydrolysis, within 60 days Retains strength for 28 days Vicryl Rapide may be used for skin closure: it provides 7–10 days of wound support
Nonabsorbable sutures			
Silk	Natural: Silkworm cocoon	Braided	Marked inflammatory reaction is induced in tissues
Ethilon	Synthetic: Nylon	Monofilament	Handle well and are often used for skin closure
Novafil	Synthetic: Polybutester	Monofilament	
Prolene	Synthetic: Polypropylene	Monofilament	May be used for skin closure or in microsurgery

[a]Absorption time and strength retention will vary with the calibre of the suture used, as well as the wound environment

14.4.5 Suture Technique (Table 14.7)

Table 14.7 Primary wound closure

Explore wounds carefully and thoroughly—they are often deeper than you think
Clean scrupulously, irrigate copiously but scrub gently. Use the tip of a pointed scalpel blade to remove grit
Avoid pinching the skin with forceps. These can crush tissue. Use one side of the forceps as a hook, or use a skin hook
Remove only dead tissue. Carefully excise wound edges. Try to ensure there is sufficient tissue to permit tension free closure
Ensure meticulous haemostasis
Align key anatomical landmarks first (vermilion border, eyebrow, eyelids, etc.). A temporary suture to approximate these landmarks may be helpful
Close in layers (mucosa to mucosa, muscle to muscle and skin to skin)
Deep sutures close dead space and reduce tension across the skin wound. This decreases the potential for abscess formation, and may reduce scar stretching
Skin sutures are used to oppose the wound edges in the most aesthetically pleasing manner. They are removed early, so should not be relied upon to hold a wound closed in the presence of tension
With complex wounds or significant tissue loss, seek help early from experienced colleagues

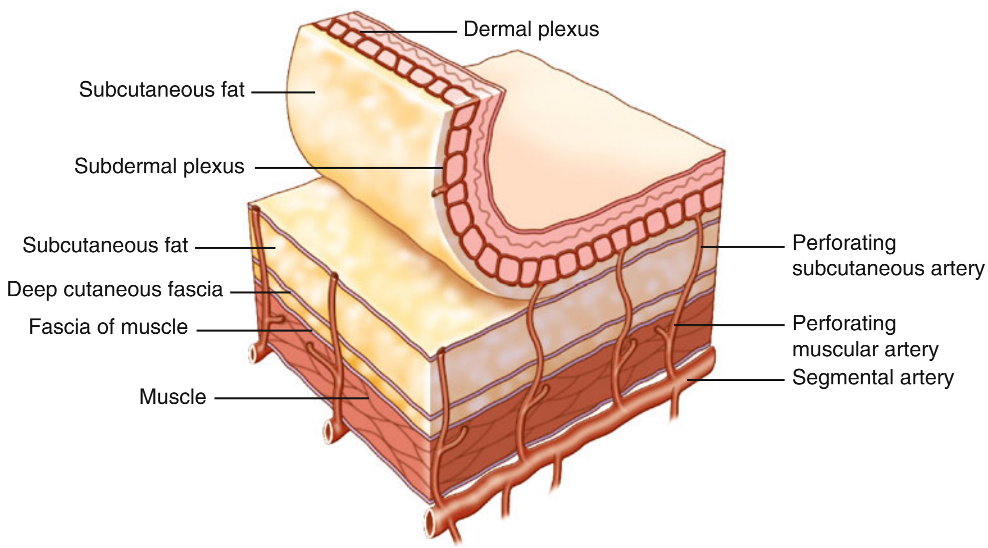

Fig 14.48 Applied skin anatomy. Thickness varies considerably. Eyelid skin is very thin

14.4.5.1 Deep Suture

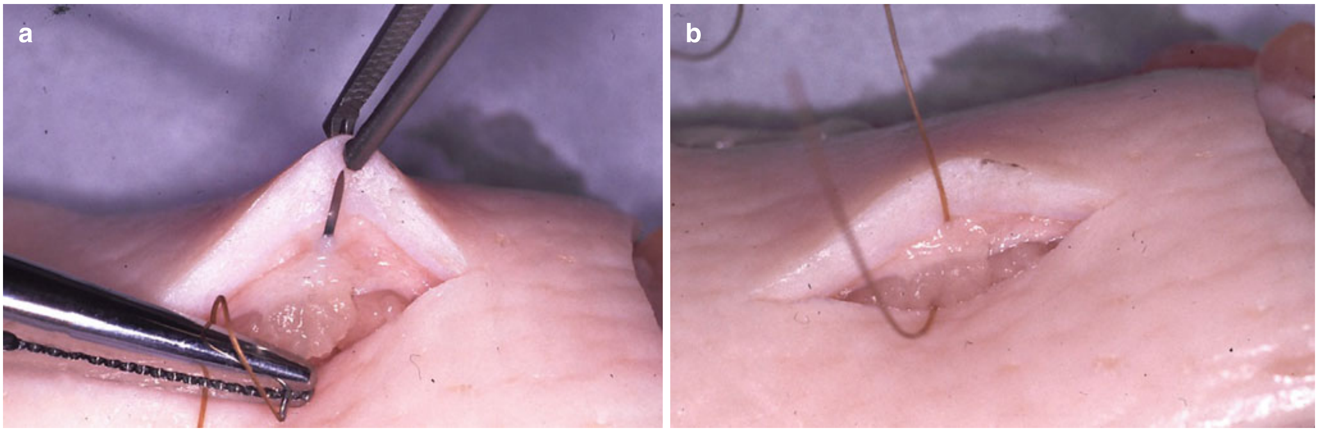

Fig. 14.49 To bury the knot the suture is passed from "deep to superficial" through the deep tissues (**a**, **b**)

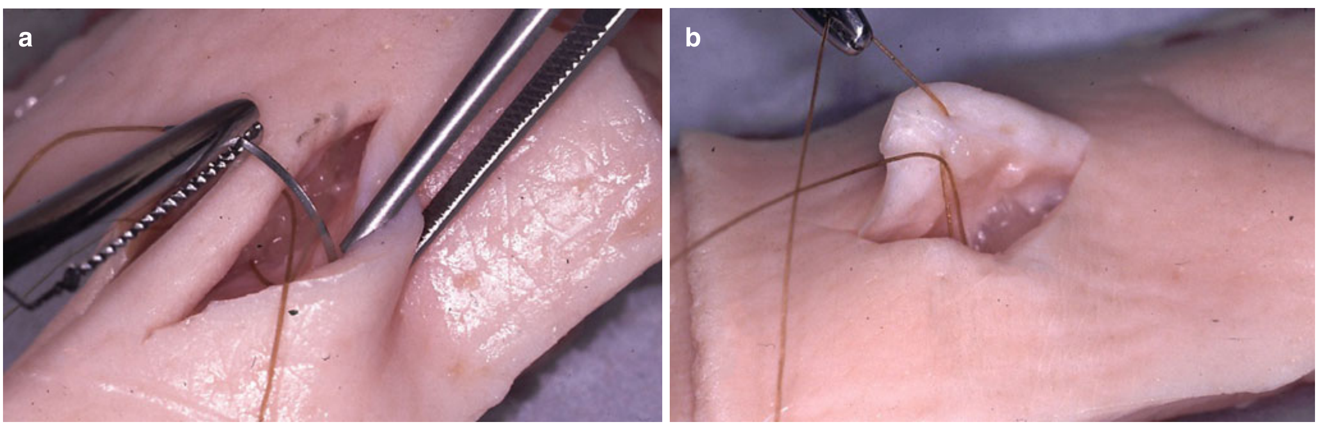

Fig. 14.50 On the opposite side it passes from "superficial to deep" (**a**, **b**)

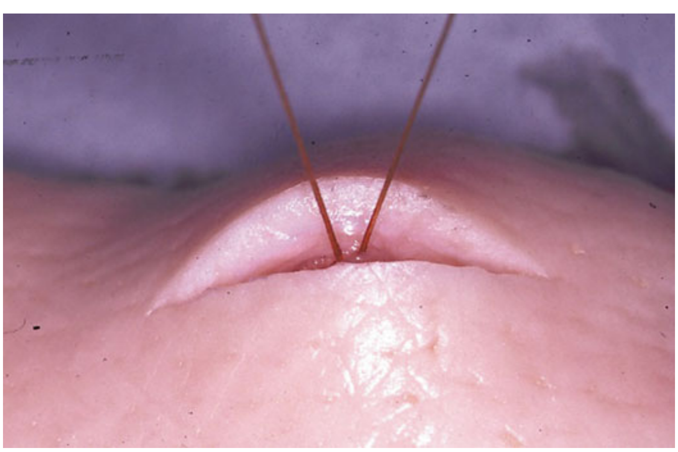

Fig. 14.51 The resulting knot will be buried

14.4.5.2 Skin Suture

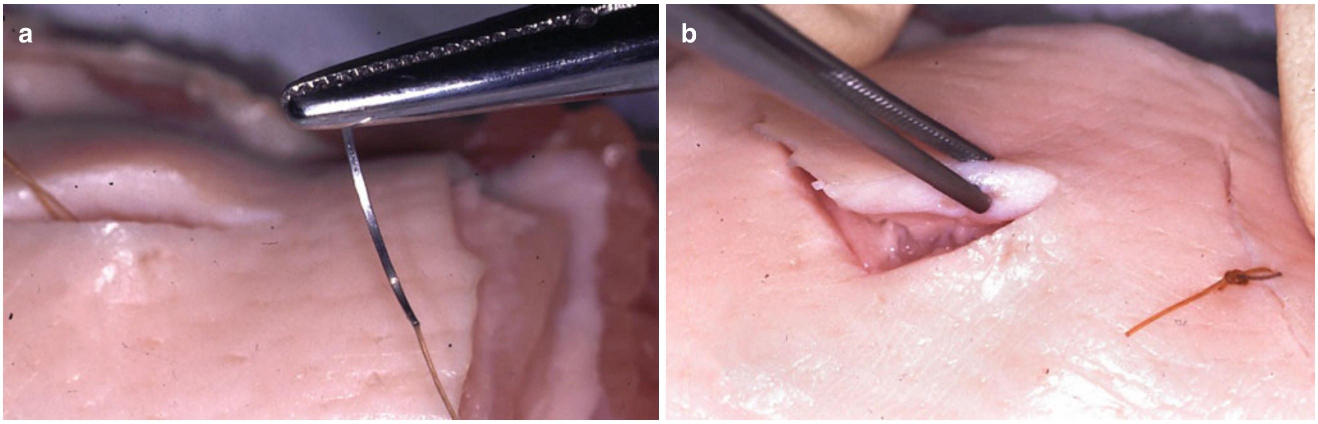

Fig. 14.52 Avoid doing these: holding tip of needle with needle holder (this will damage it) and grabbing skin with forceps (this will crush the tissue) (**a**, **b**)

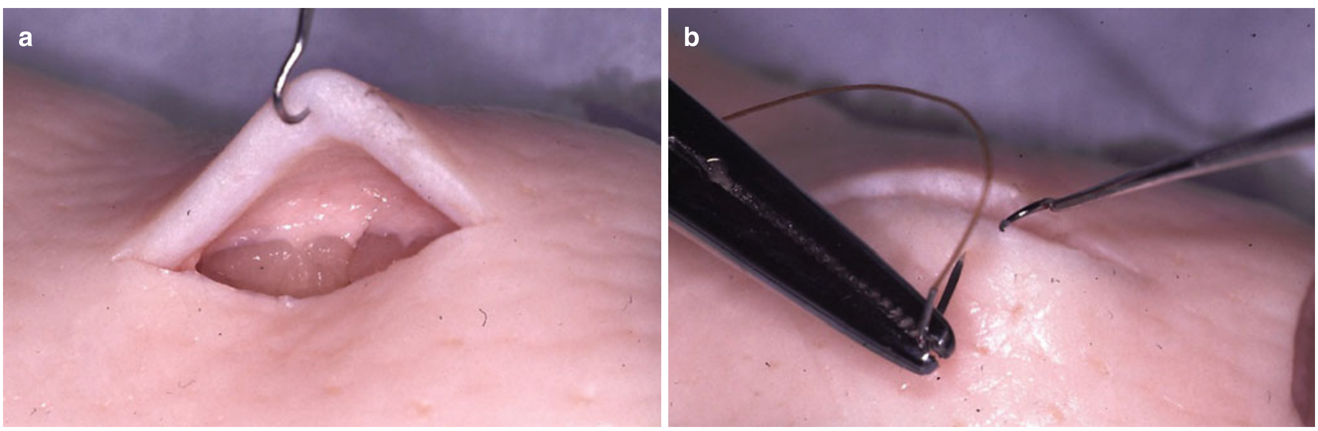

Fig. 14.53 Ideally use a skin hook. Rotate the needle through the skin (**a**, **b**)

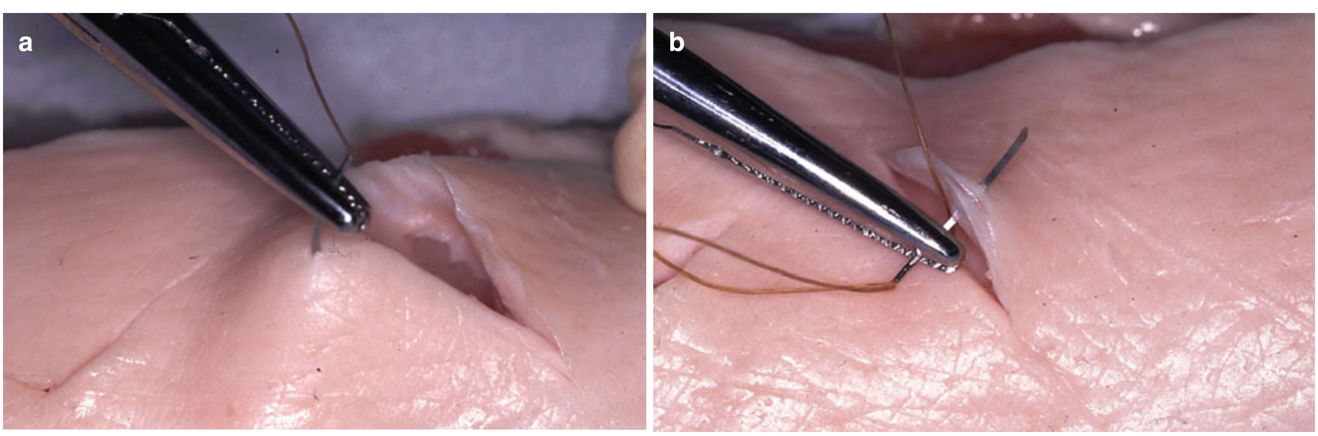

Fig. 14.54 With most wounds, take equal size "bites" of the skin (**a**, **b**)

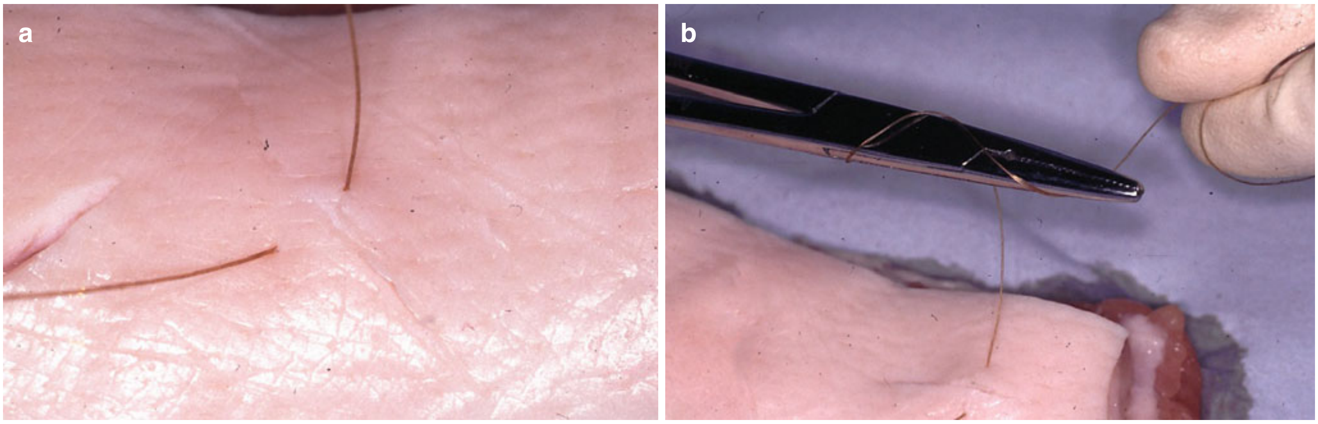

Fig. 14.55 Following placement the first "throw" of the knot is made (**a**, **b**)

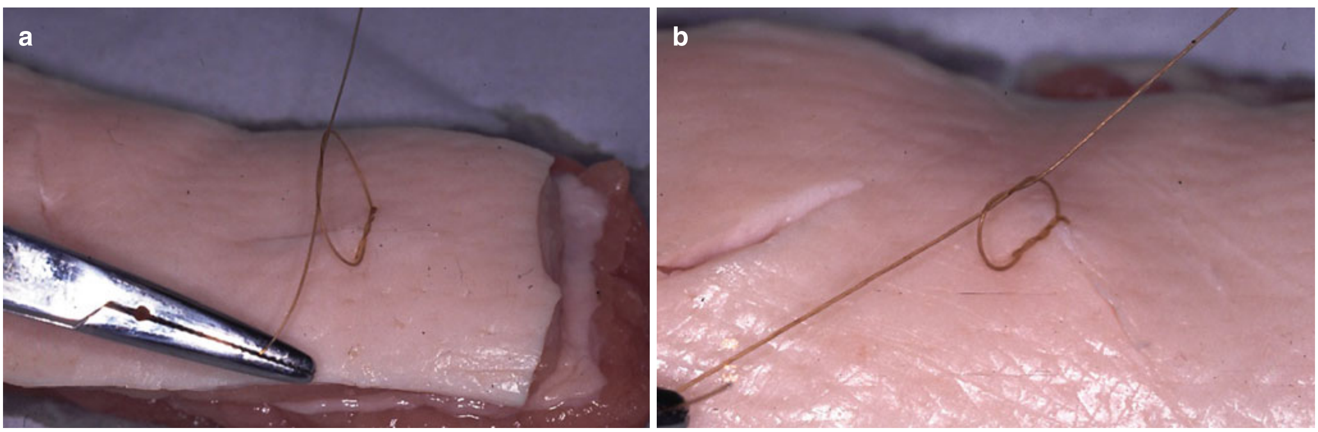

Fig. 14.56 The knot needs to be correctly aligned. A second throw adjusts tension. A third locks the whole knot (**a**, **b**)

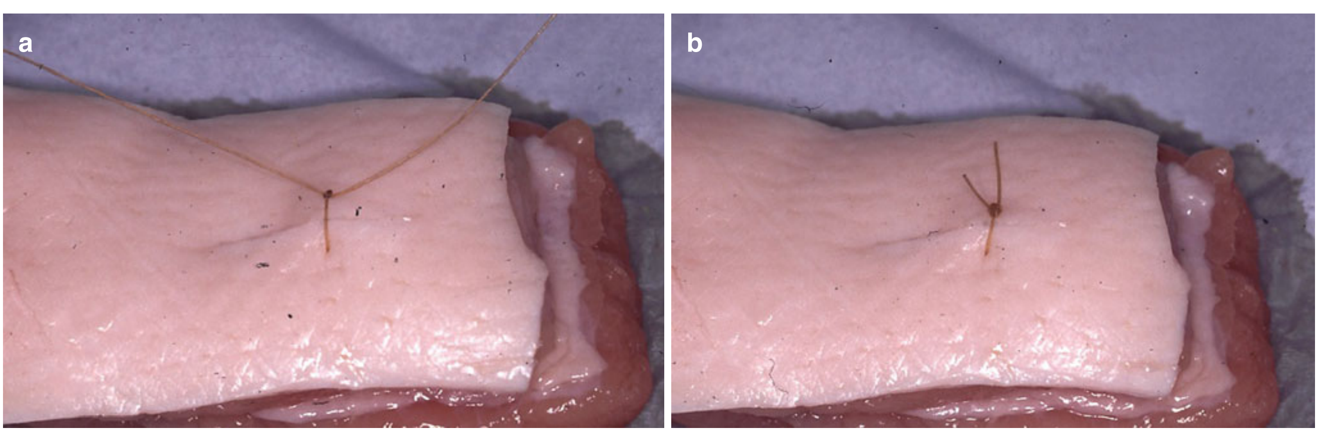

Fig. 14.57 Final knot, which is cut long enough to allow removal (**a**, **b**)

14.4.5.3 Apical Suture

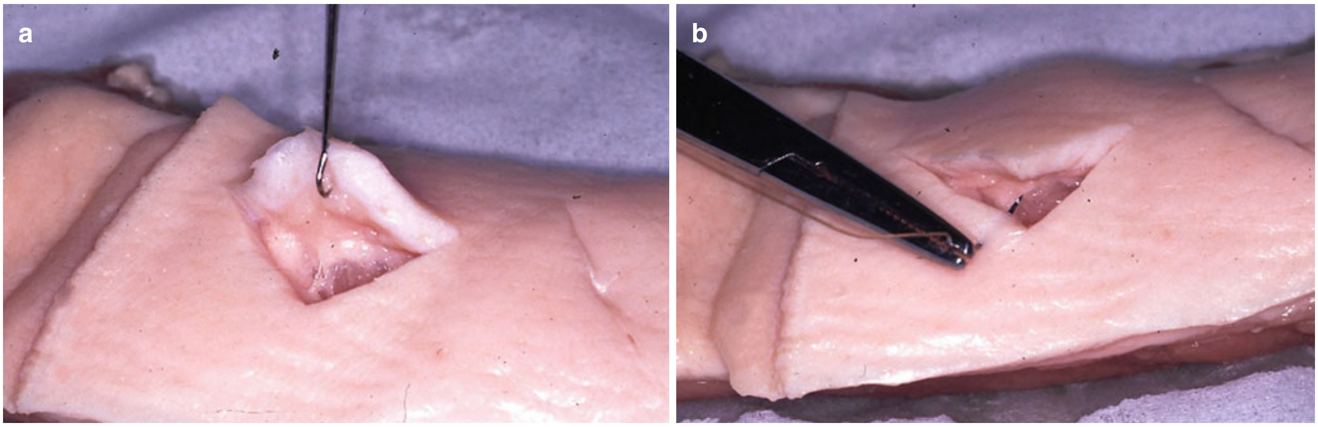

Fig. 14.58 These need to be placed carefully. If too tight, the apical tissue can necrose. An initial full-thickness bite is taken (**a**, **b**)

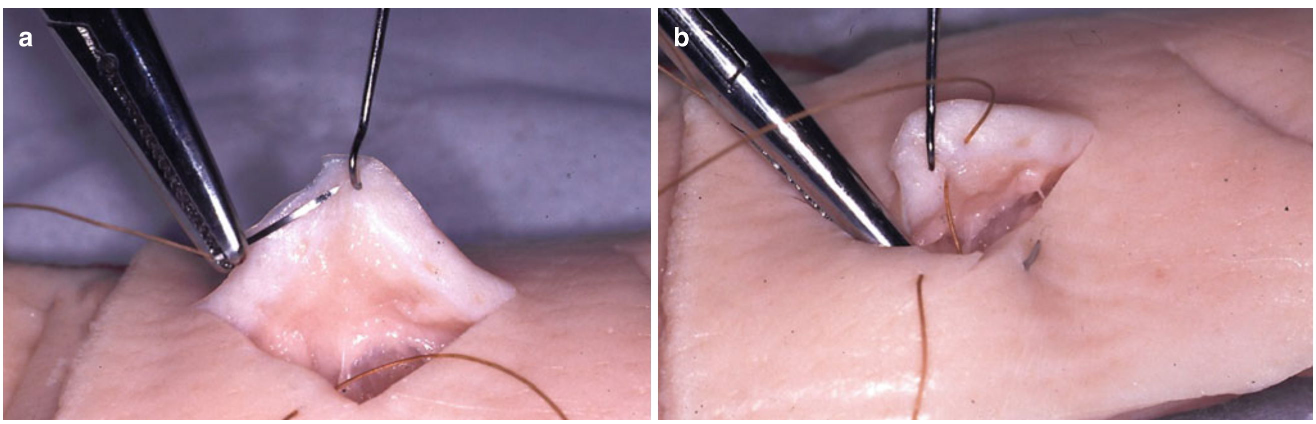

Fig. 14.59 This is passed through the subcuticular portion of the apex. A second full-thickness bite is then taken in the opposite skin (**a**, **b**)

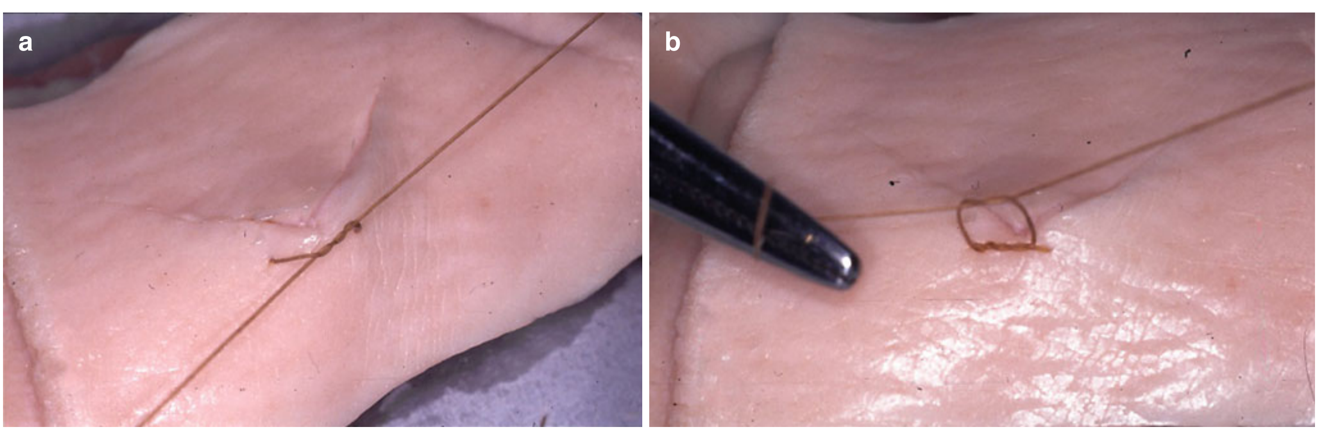

Fig. 14.60 When tightened, the knot brings together the three points (**a**, **b**)

Case 1 (Child)

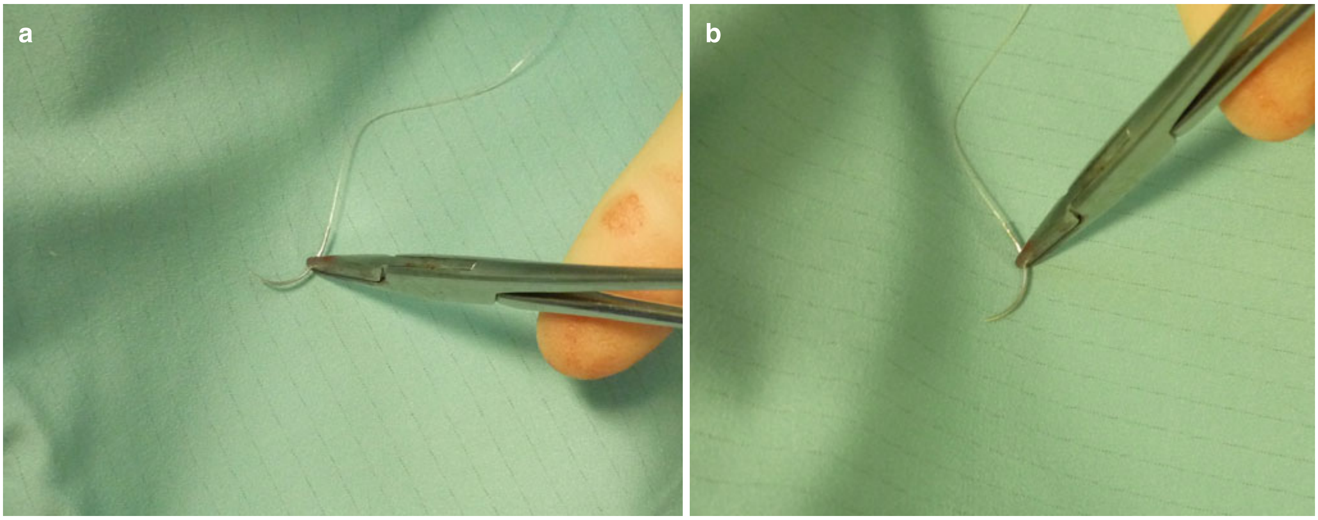

Fig. 14.61 Suturing usually requires delicate sutures and needles. These must be held correctly (i.e., approximately midway along the needle). If the ends are held, either the cutting tip will be damaged or the needle will deform on use (**a**, **b**)

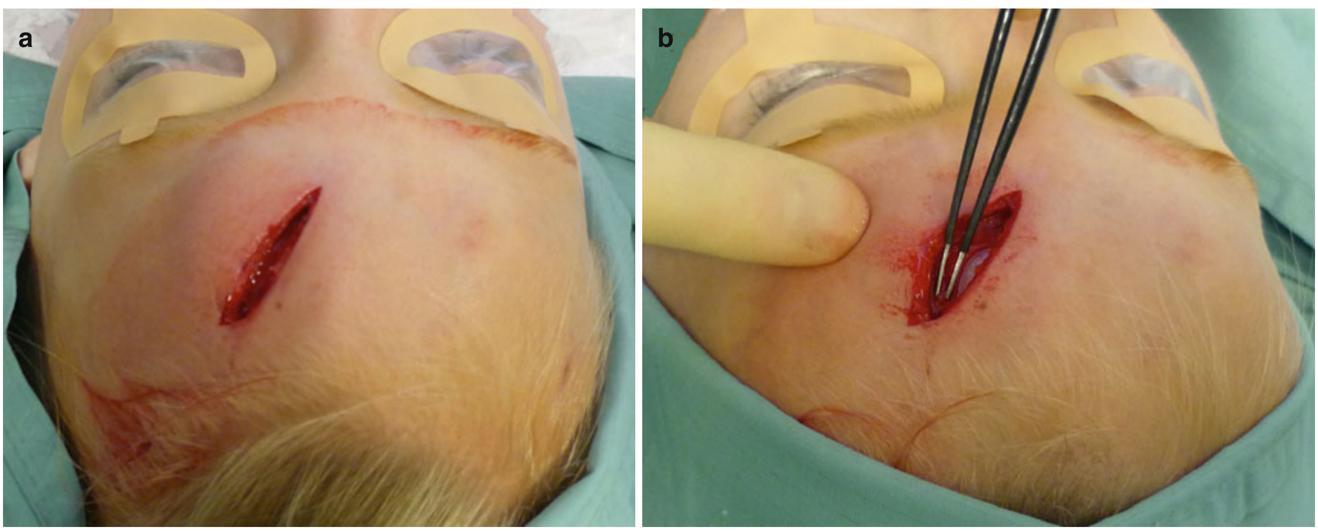

Fig. 14.62 The full-thickness wound is examined with particular attention to haemostasis (a small child) (**a**, **b**)

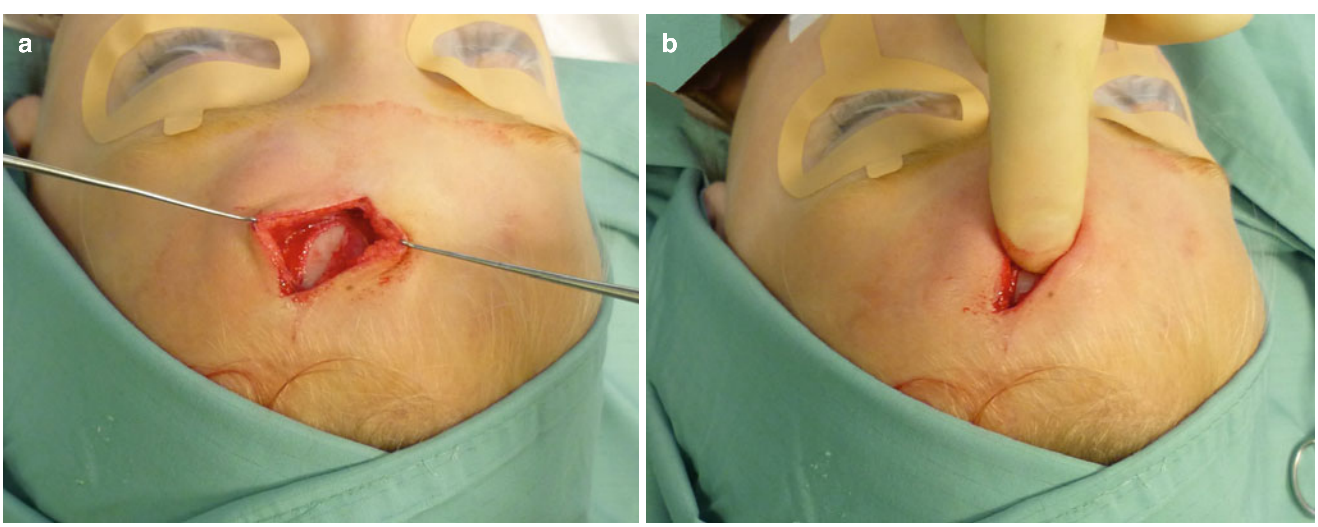

Fig. 14.63 The wound is carefully assessed for depth, underlying fractures and FBs (**a**, **b**)

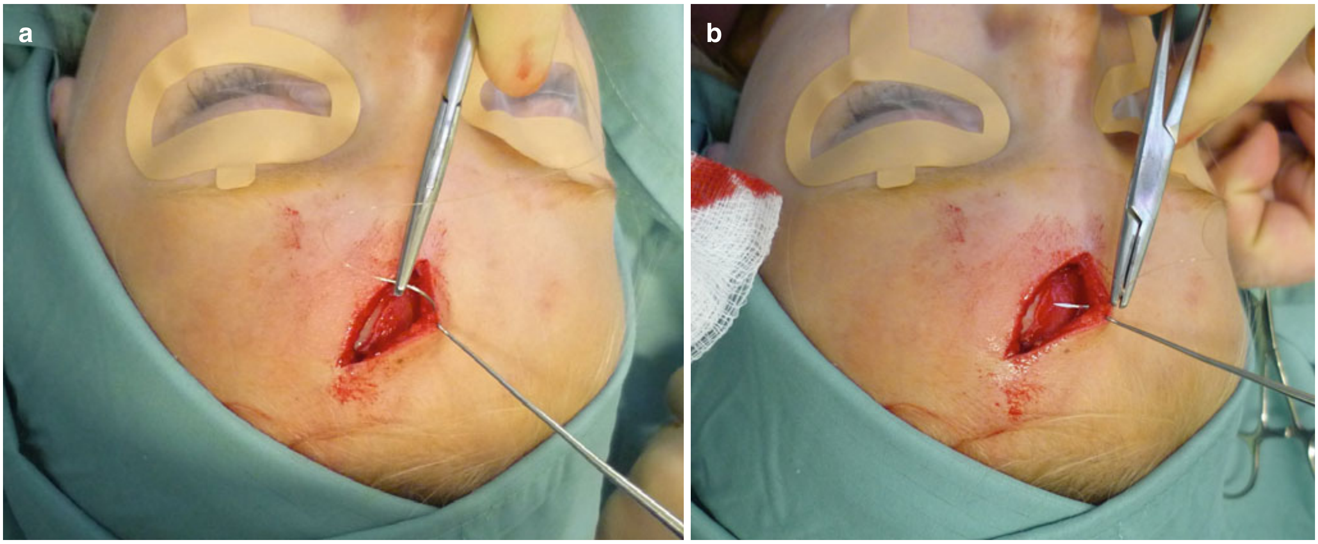

Fig. 14.64 Placement of deep suture. The periosteum often cannot be sutured, as in this case. This is not essential (**a**, **b**)

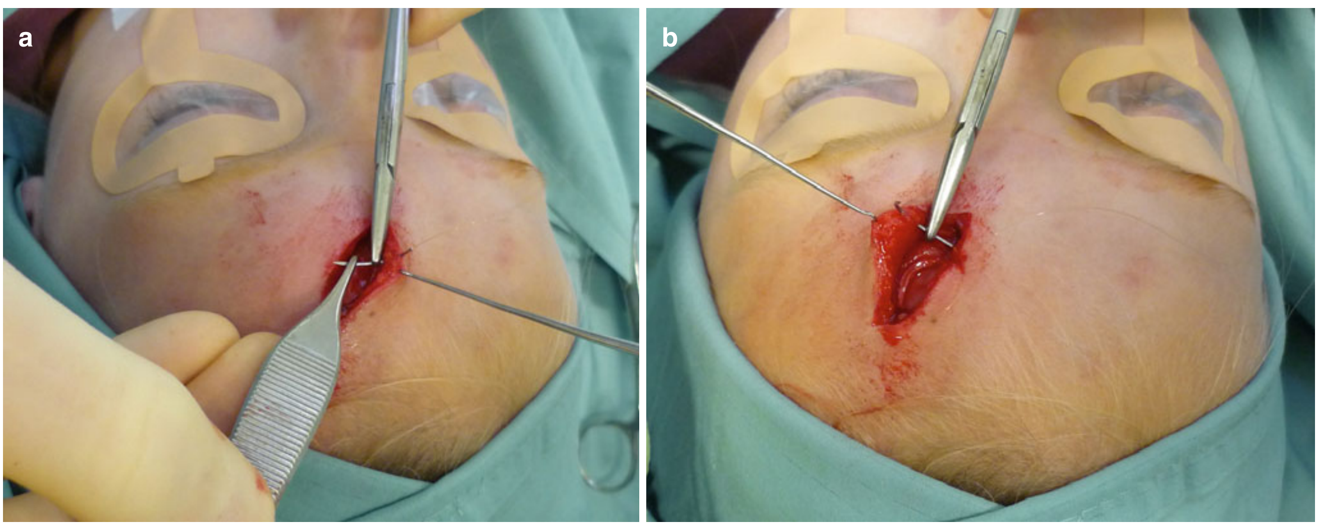

Fig. 14.65 The needle is carefully rotated through the deep tissues on one side, then passed through the opposite side (**a**, **b**)

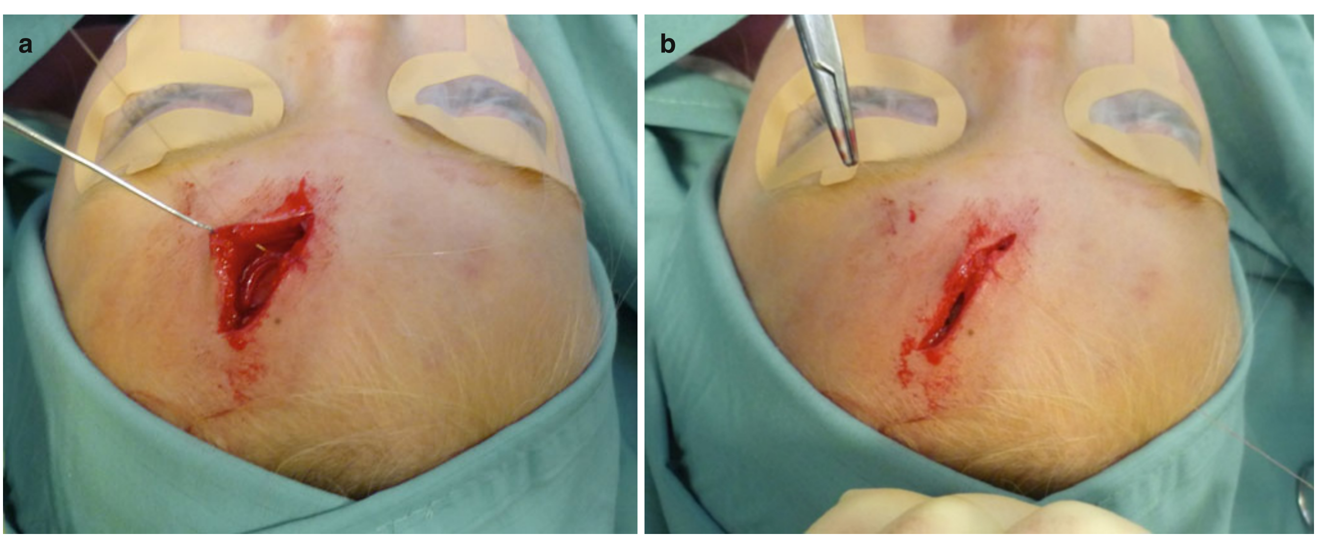

Fig. 14.66 The suture is gently pulled through and then tied (**a**, **b**)

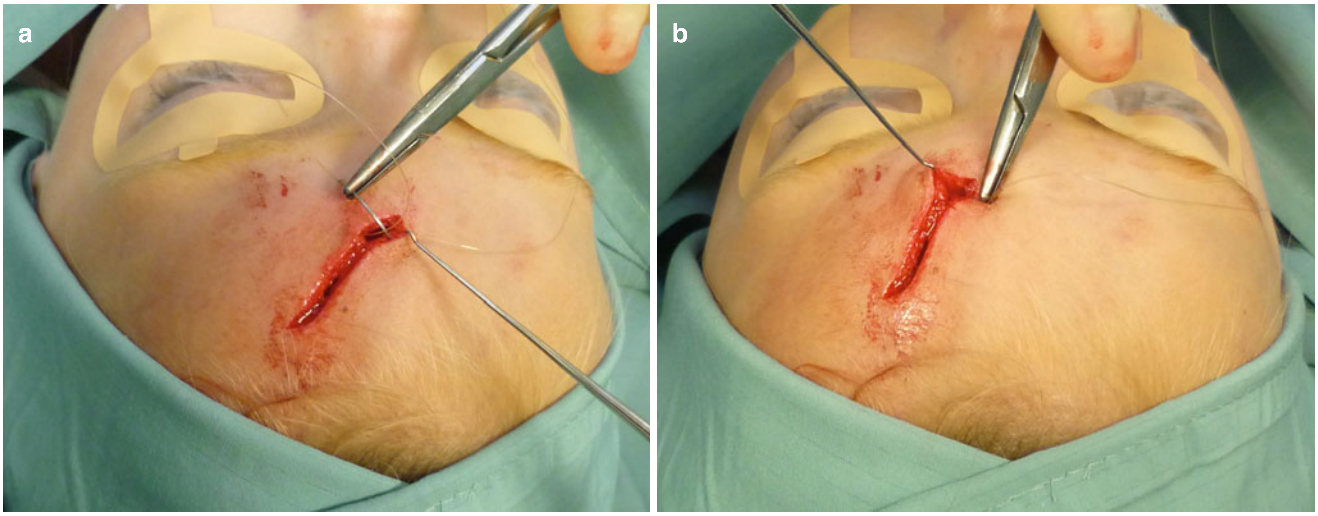

Fig. 14.67 This is repeated along the length of the wound to provide sufficient deep support (**a**, **b**)

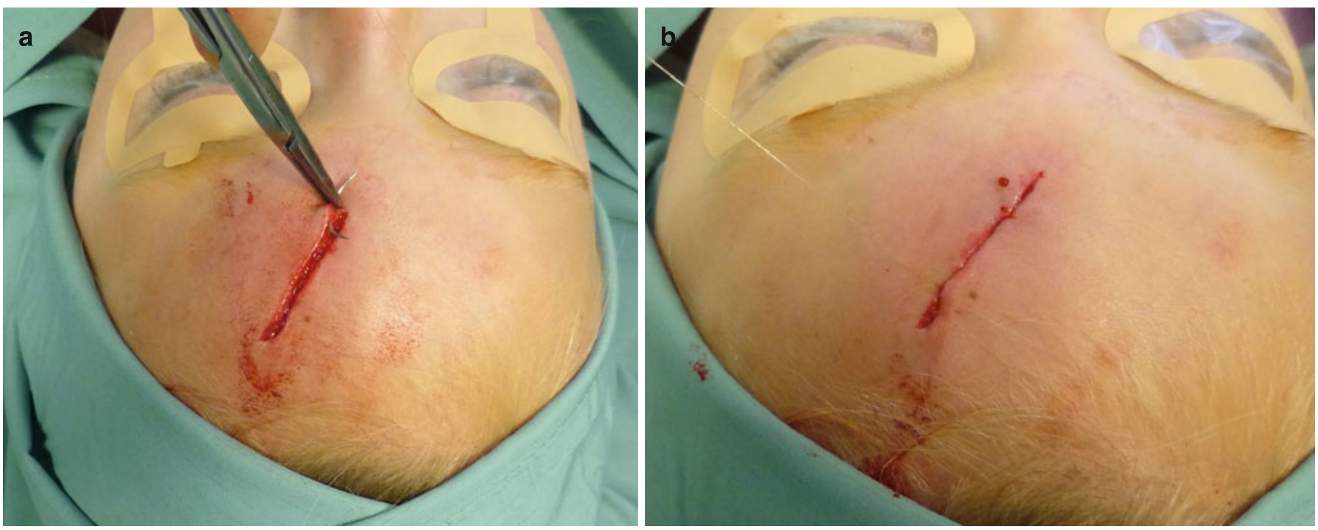

Fig. 14.68 Skin closure is performed using a fine resorbable subcuticular suture (**a**, **b**)

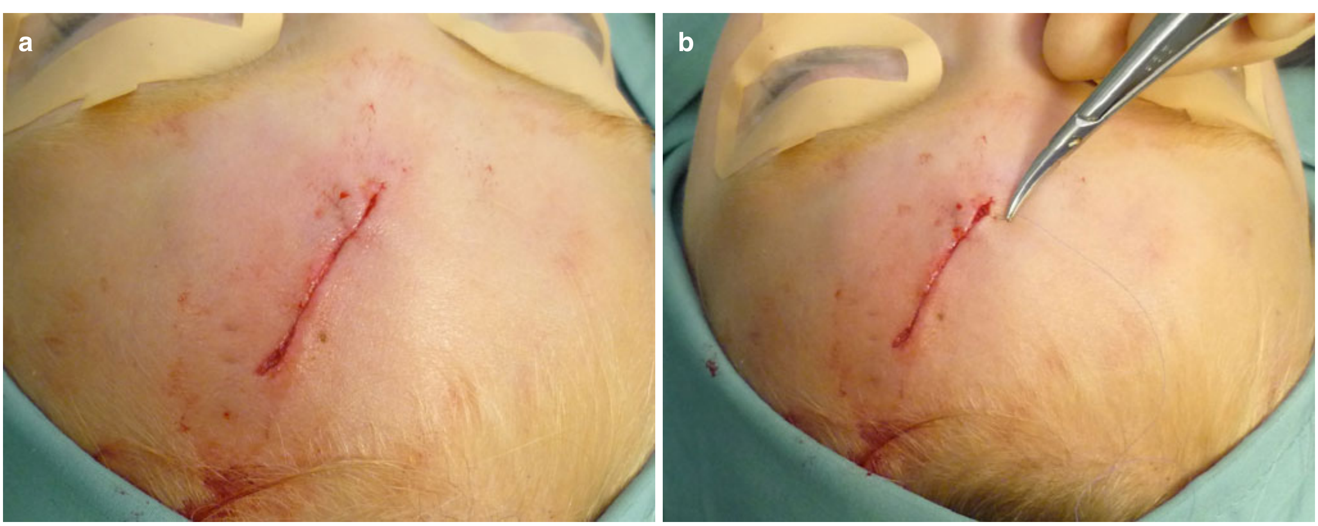

Fig. 14.69 If required, a few very fine resorbable sutures can be placed through the skin (**a**, **b**)

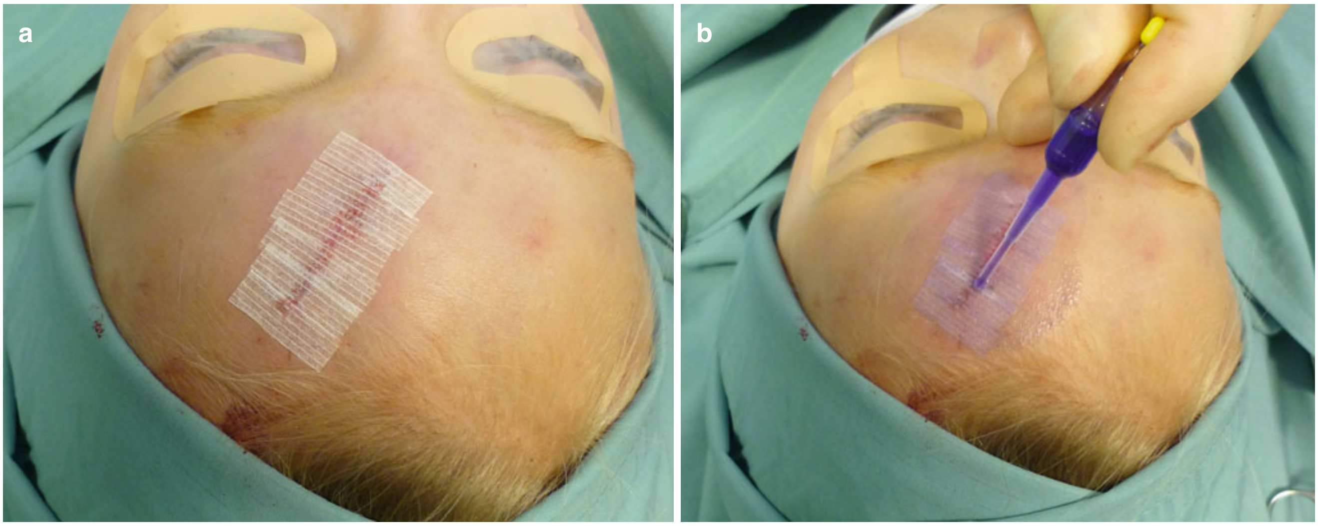

Fig. 14.70 The wound is finally supported with adhesive tape (**a**). Some surgeons supplement this with cyanoacrylate (**b**)

Case 2 (Adult)

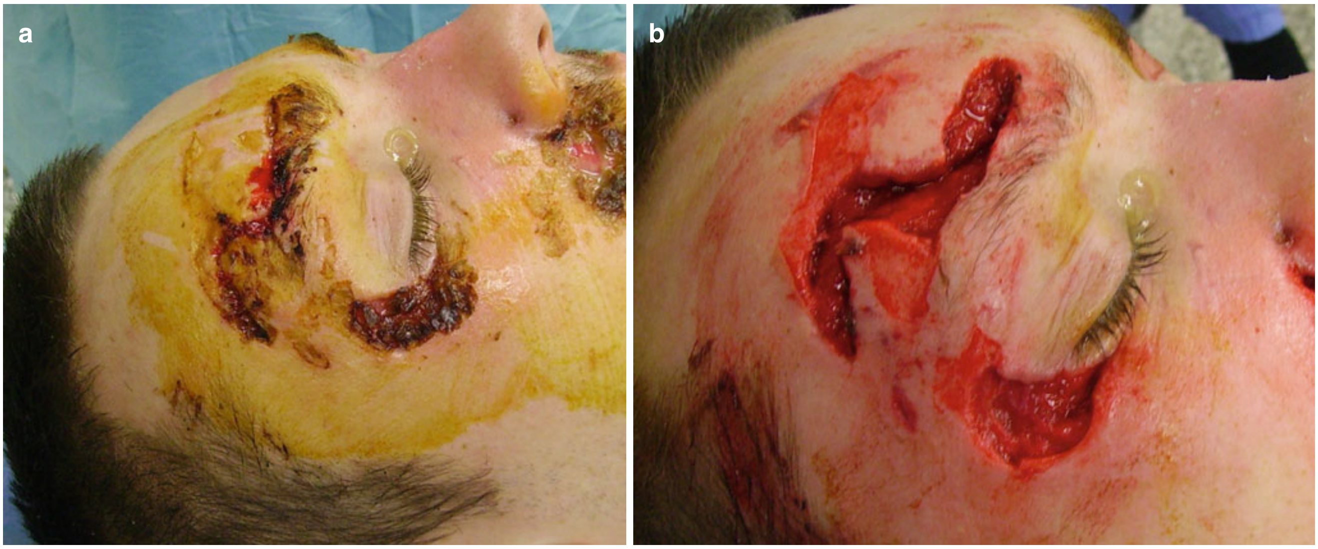

Fig. 14.71 Delayed primary closure of facial wounds following car-versus-pedestrian injury. Wound is cleaned and debrided as required (**a**). Abrasions have been cleaned (**b**)

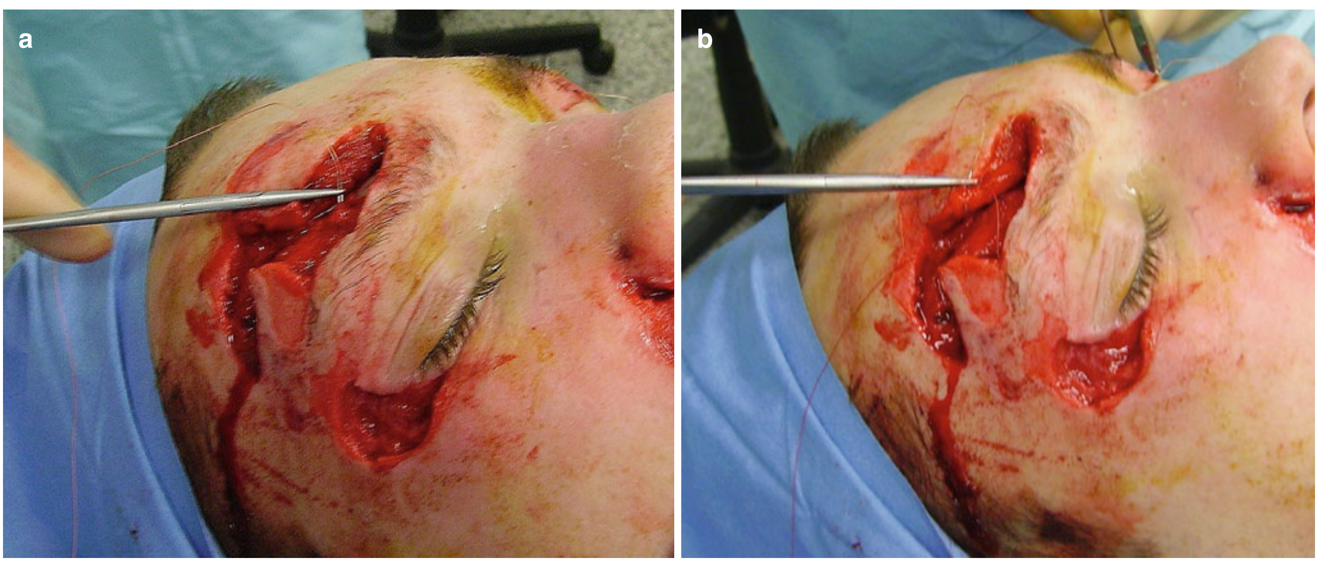

Fig. 14.72 Closure of deep layers using resorbable suture (**a**, **b**)

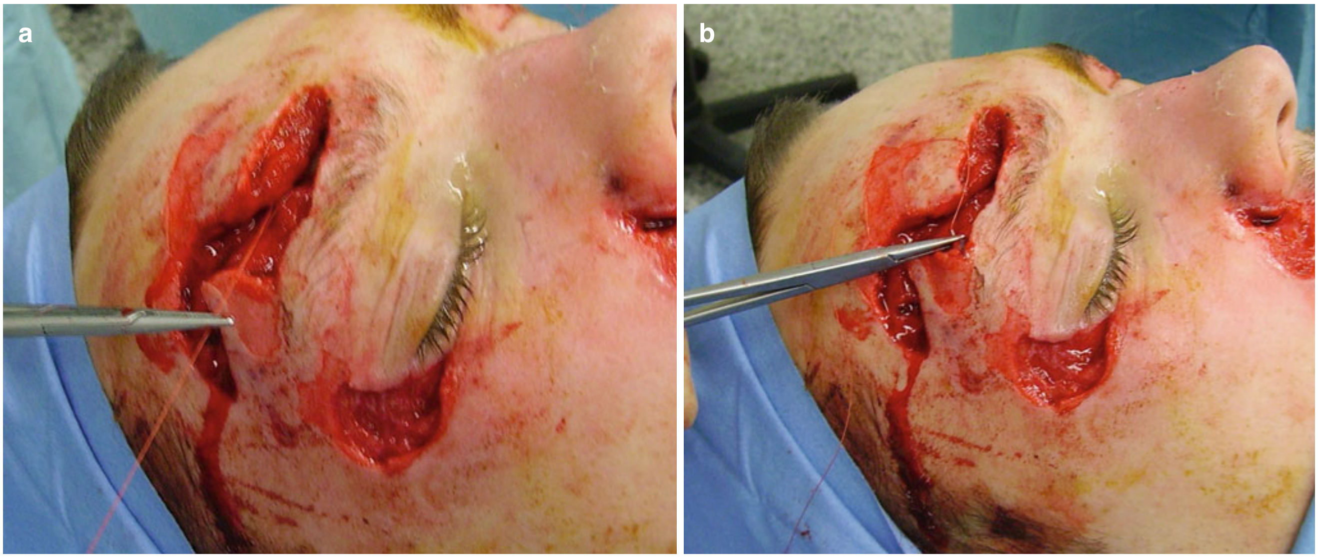

Fig. 14.73 Closure of deep layers using resorbable suture (**a**, **b**)

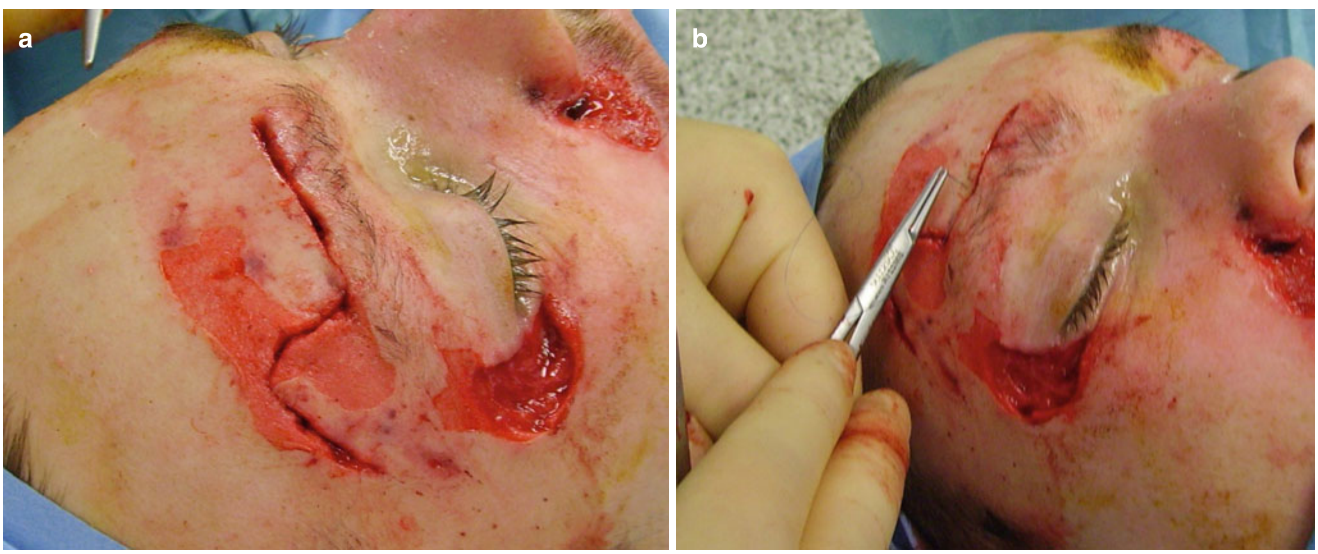

Fig. 14.74 Following deep sutures, the wound is now ready for skin. Interrupted full-thickness sutures are used (**a**, **b**)

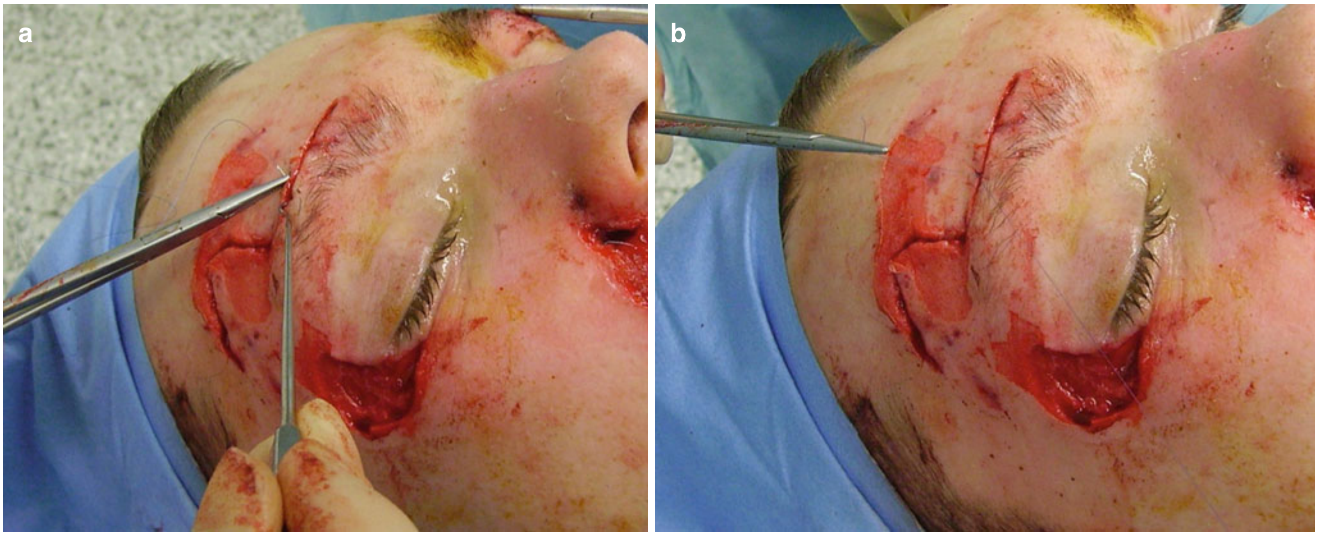

Fig. 14.75 Avoid holding the skin with forceps. Use a skin hook whenever possible (**a**, **b**)

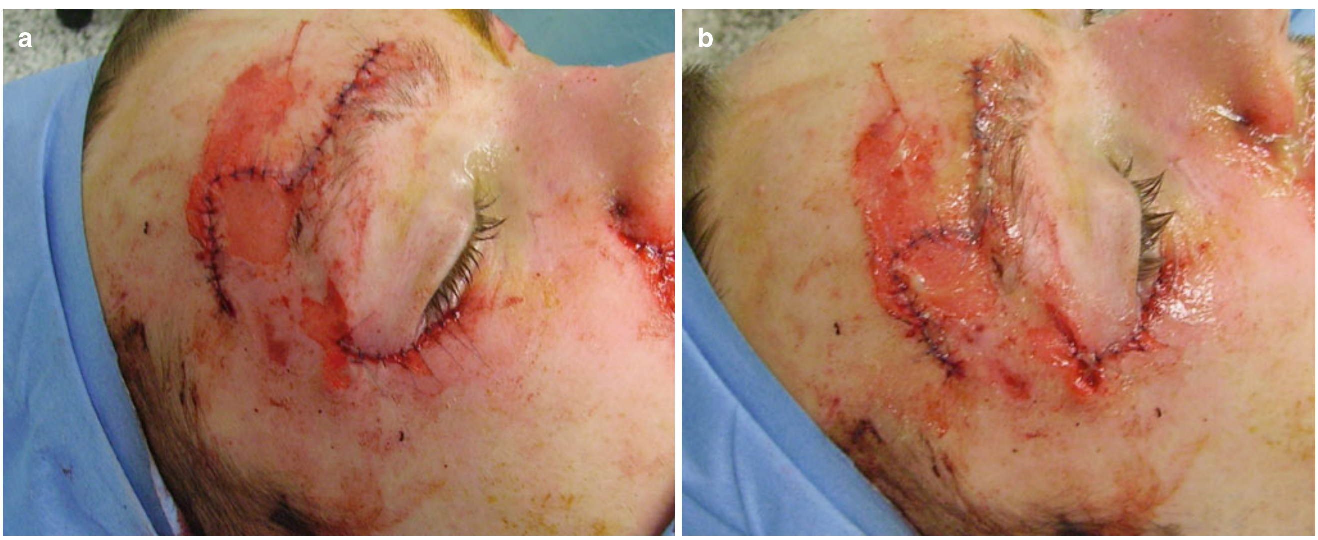

Fig. 14.76 Following skin closure the wound is protected with an antibiotic cream (chloromycetin) (**a**, **b**). The routine use of this is controversial

Case 3

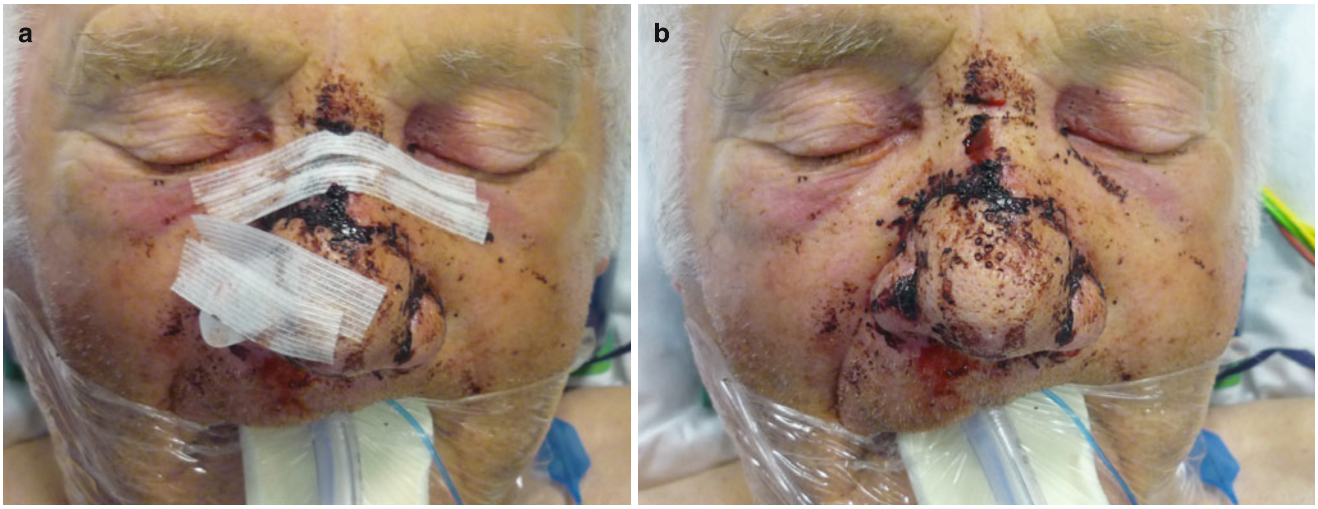

Fig. 14.77 Patient presented following a fall at home (into glass table) (**a**, **b**)

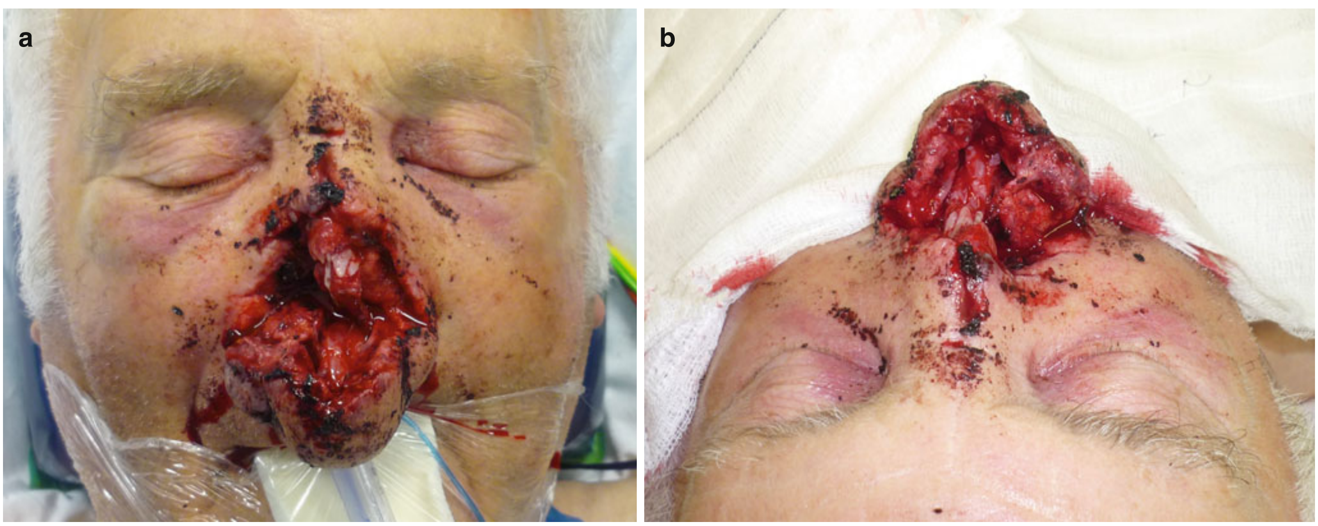

Fig. 14.78 Examination under anaesthesia confirmed a full-thickness laceration through the nose with partial amputation (**a**, **b**)

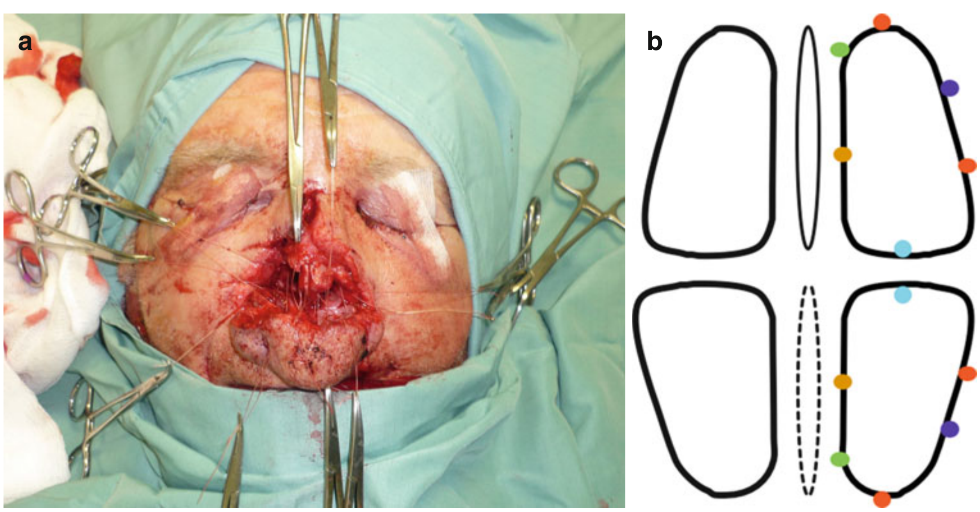

Fig. 14.79 Repair of the lining mucosa often requires placement of all sutures before the knots are tied. Corresponding bites on both sides of the wound are taken (**a**, **b**)

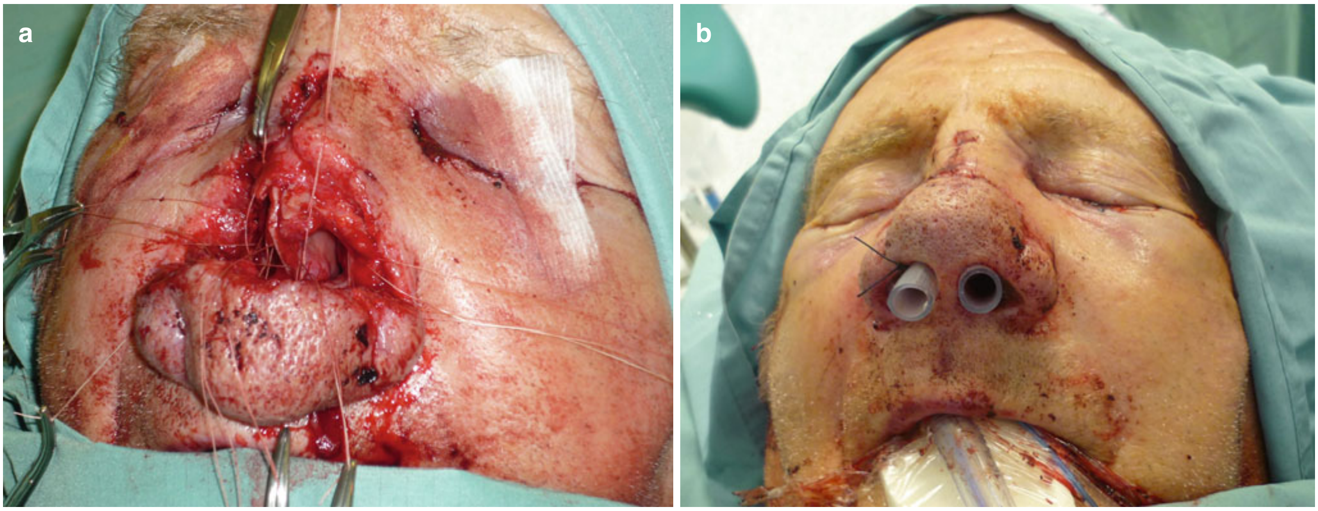

Fig. 14.80 The nasal lining is closed first starting from the deepest points, working superficially. The remaining layers of the nose are then closed (**a**). Stents may be required (**b**)

Fig. 14.81 Six weeks postoperatively

14.4.6 Prolonging Wound Support

Early removal of sutures should be combined with continued support from an adhesive paper dressing, e.g., Micropore tape or Steri-Strips. This reduces the risk of wound dehiscence due to loss of support. Remember that the underlying muscles will be active and may act to separate the wound during talking, eating, facial expression etc. Prolonged use of adhesive strips helps reduce stretching of the immature scar, although it is unlikely that patients will continue with this for any considerable time.

Elective skin incisions are often planned to lay in one of the relaxed skin tension lines (also referred to as “RSTL” or “Langer’s lines”). These tend to heal well and mature into acceptable scars that mimic or are disguised by natural wrinkles. Unfortunately, this luxury is not always available when managing traumatic wounds which may be sited unfavourably (i.e., perpendicular to the RSTL). These are more likely to heal poorly and stretch. Stretching occurs for a number of reasons, but the two main contributors are the weight of the tissues themselves and activity of the deeper facial muscles during the prolonged healing period. For this reason a number of strategies have been developed (see Table 14.8), some or all of which may help minimise this. The logic behind these is to minimise perpendicular forces across the wound.

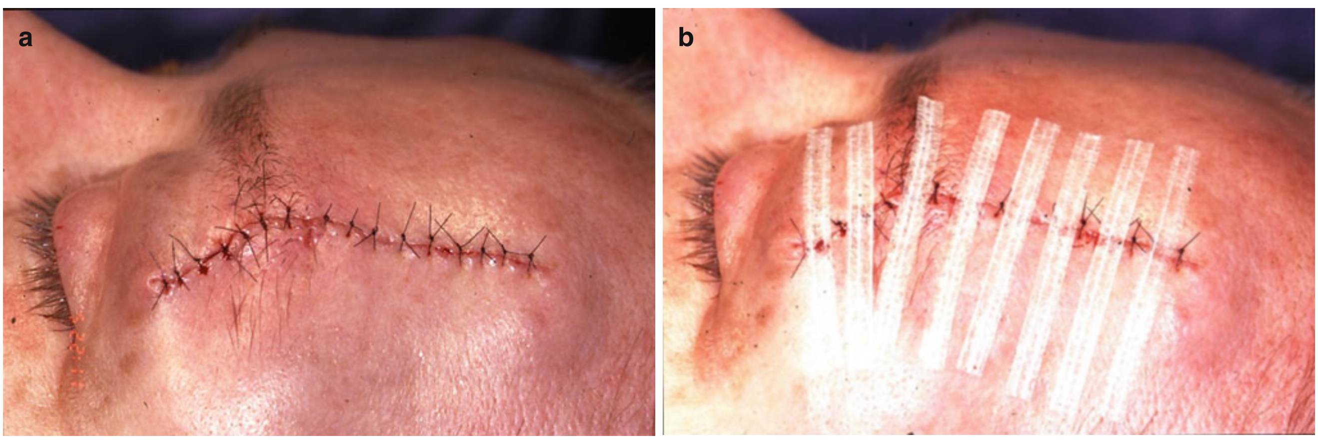

Fig. 14.82 Adhesive paper tape (Steri-Strips) provides extra wound support during healing. They should be placed across the wound, rather than along it. They should ideally be used for long-term support (**a**, **b**)

Table 14.8 Prolonging wound support

Use slowly resorbing, or even nonabsorbable sutures to close the deep tissues. Synthetic monofilaments produce minimal tissue response and have good properties of strength retention
Make sure the knots are deeply buried—they can sometimes become exposed and form a small stitch abscess
Close the skin with an absorbable, intradermal (“subcuticular”) suture. This can be left in situ for months, without the risk of cross-hatching. An alternative is to use a nonabsorbable subcuticular suture, loosely knotted at the ends. Leave both ends visible, and tape them securely in place. When healed, the tape can be removed, and one end of the suture grasped. The other knotted end is cut and the suture can then be drawn out of the wound, leaving no suture marks
Place adhesive paper strips across (not along) the wound. This is especially important once the skin sutures have been removed. Taping of the wound may be necessary for months, and require daily change. Not surprisingly many patients fail to comply
The use of botulinum toxin (botox), injected into the surrounding muscles has been reported
Avoid massage of the scar if there are no signs of hypertrophy. If necessary refer to an Occupational Therapist (or some other appropriate specialist) with an interest in scar management. They can advise patients on massage techniques and the use of silicone dressings to promote scar maturation

14.4.6.1 Subcuticular and Deep Prolene Suture

Subcuticular sutures may be kept in place for longer, as scarring is less likely.

Case 1

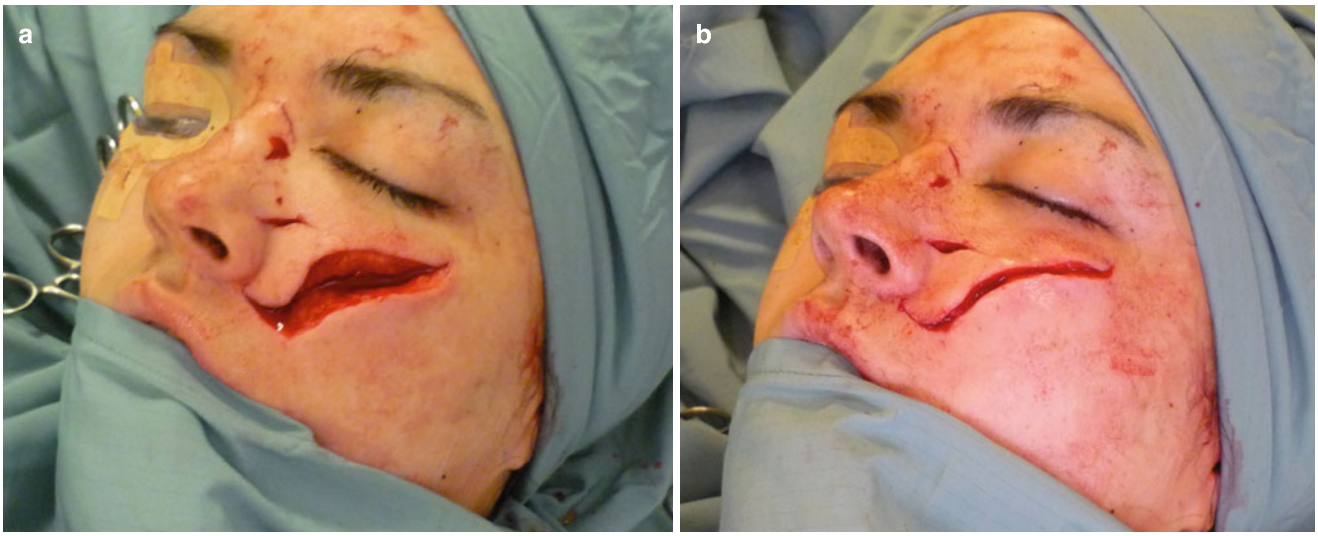

Fig. 14.83 Deep incised wound following glass injury. Deep sutures placed using PDS (long absorption time). Skin was closed with subcuticular prolene (**a**, **b**)

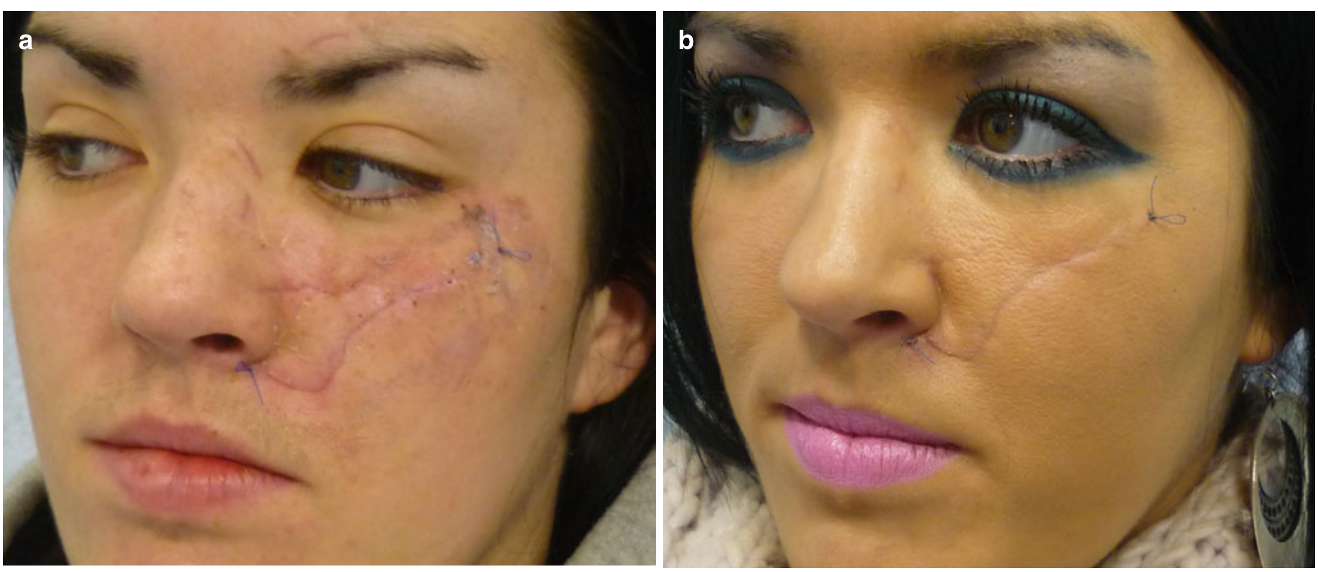

Fig. 14.84 Appearances at 2 weeks (**a**) and 6 weeks (**b**). Aftercare is very important at this stage

Fig. 14.85 Subcuticular suture was removed at 3 months

Case 2

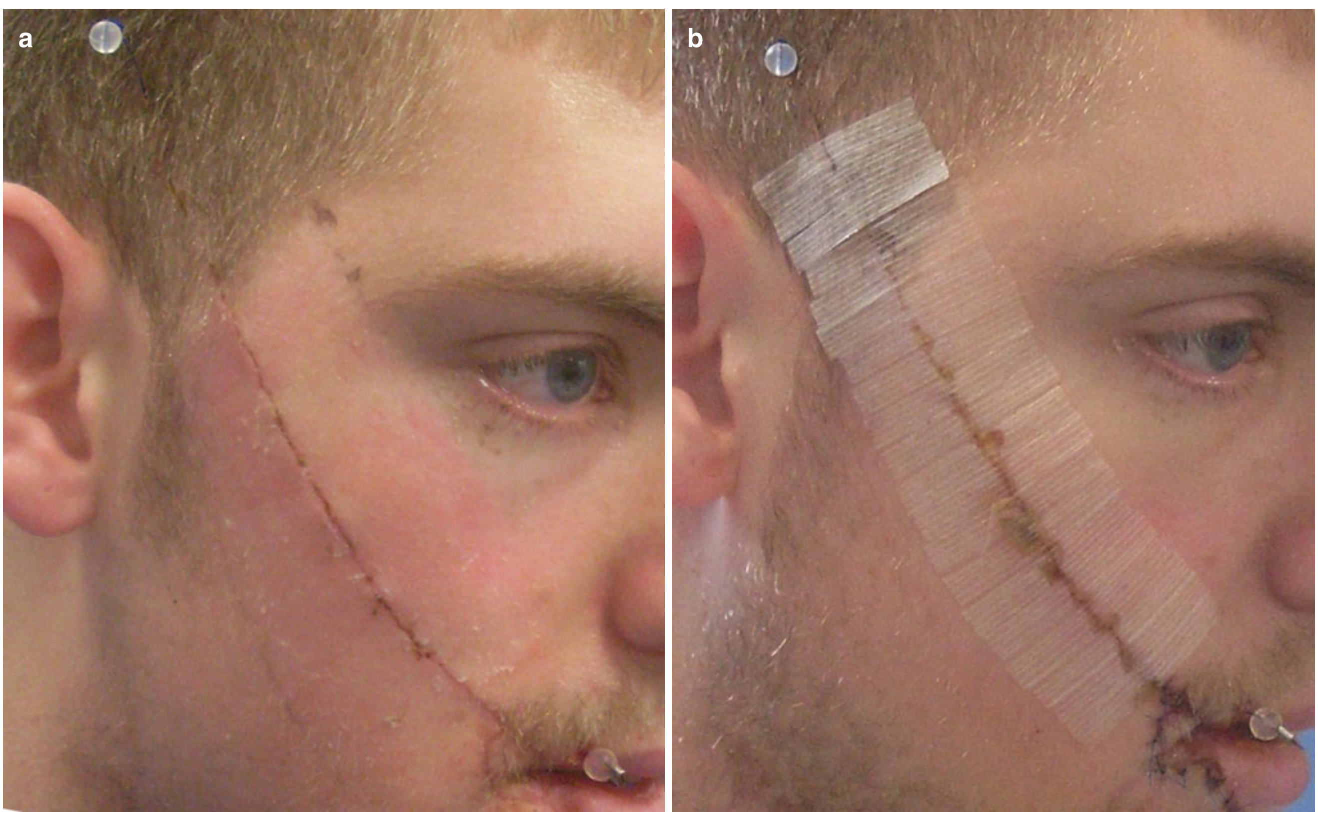

Fig. 14.86 Oblique lacerations across the face are at high risk of scarring poorly. A nonabsorbable subcuticular suture and prolonged use of adhesive strips provides long-term support. The suture remained in situ for 2 months (**a**, **b**)

14.5 Delayed Closure and Crushed Tissues

This may be unavoidable in patients with coexisting and more pressing injuries, but unfortunately results in poorer outcomes. Ideally, thorough wound lavage and debridement should be undertaken as a preliminary stage, depending on the degree of contamination and anticipated delay in definitive management. Only minimal debridement is necessary as preservation of tissue is the rule. With partially avulsed skin, a small pedicle may still have surprisingly enough vascularity if it is expeditiously realigned. If in doubt, preserve tissue—never excise radically unless it is absolutely necessary. Remember that facial tissues have a remarkable capacity for healing. If there is a significant delay or the wound has been heavily contaminated, consider the use of drains.

Case 1

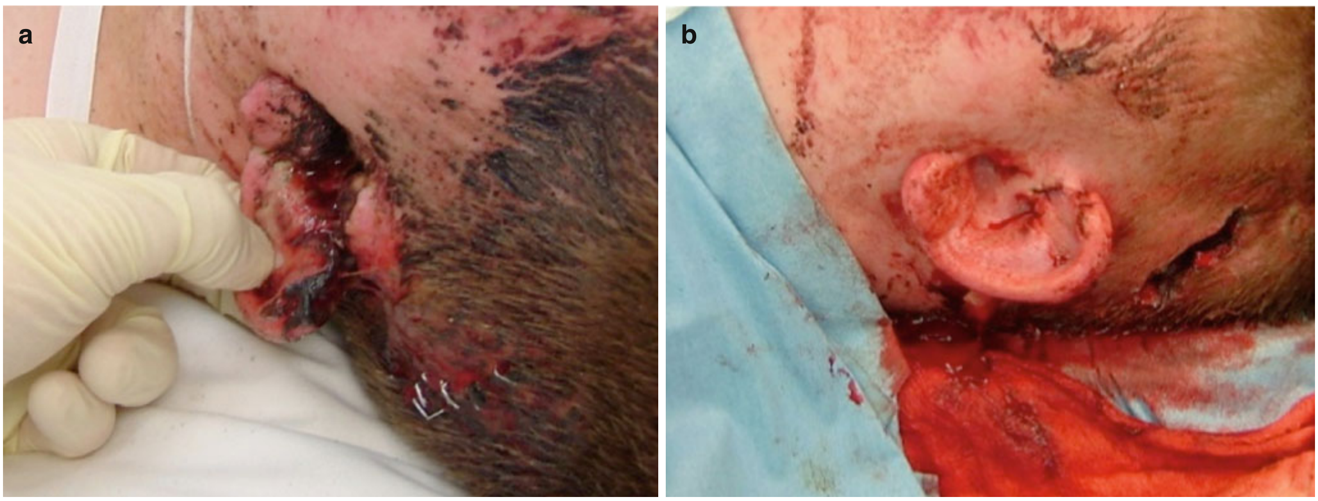

Fig. 14.87 Delayed repair of crush injury and partial avulsion of an ear (patient was ejected from a car). The ear has maintained much of its viability. It was minimally debrided and repaired (**a**, **b**)

Fig. 14.88 Result at 1 month

Case 2

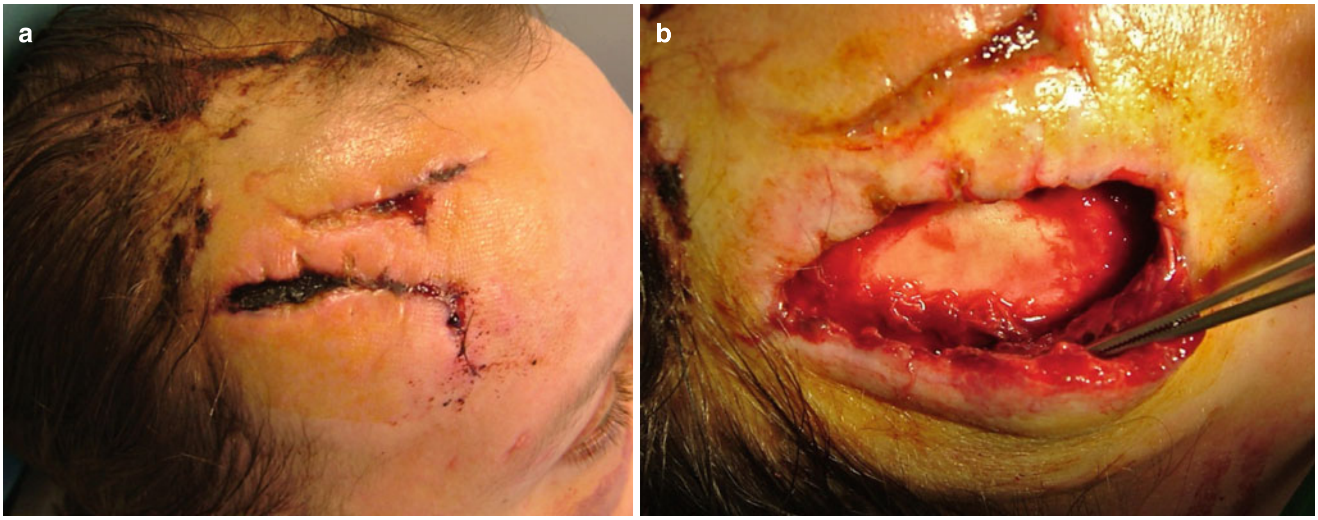

Fig. 14.89 Delayed presentation of a scalp wound (hit by a brick). Patient did not seek medical attention until it became infected. Exploration revealed a full-thickness wound with infected haematoma and multiple small FBs (**a**, **b**)

Fig. 14.90 The wound was loosely closed and a drain placed for 48 h

Case 3

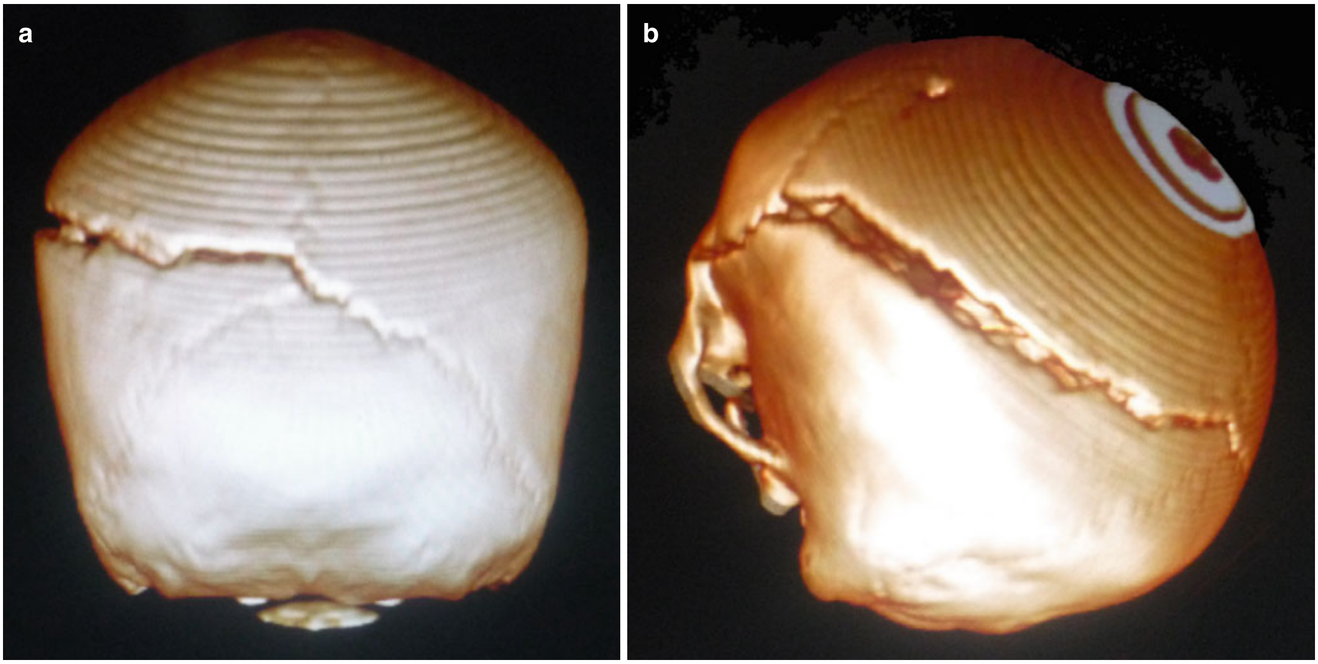

Fig. 14.91 Delayed presentation of a scalp wound overlying a significant skull fracture. Patient had fallen from a tractor and was run over by its trailer (**a**, **b**)

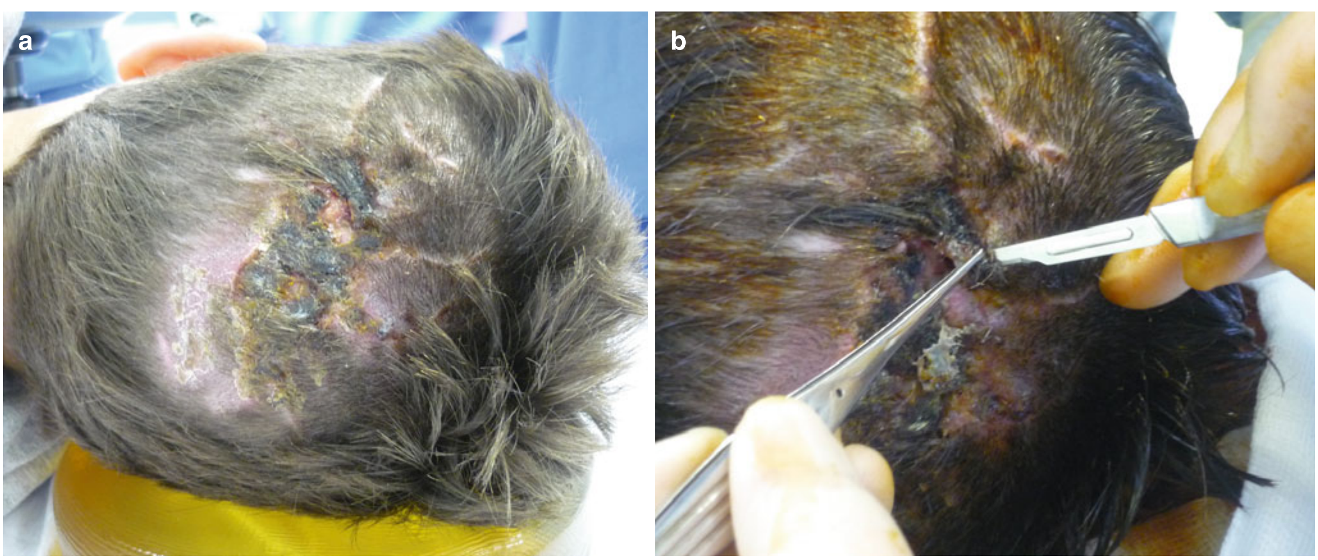

Fig. 14.92 The wound had been sutured previously but was breaking down and infected (**a**, **b**)

Fig. 14.93 Initial appearances after skin debridement. Note extensive loss of skin and exposed bone (**a**, **b**)

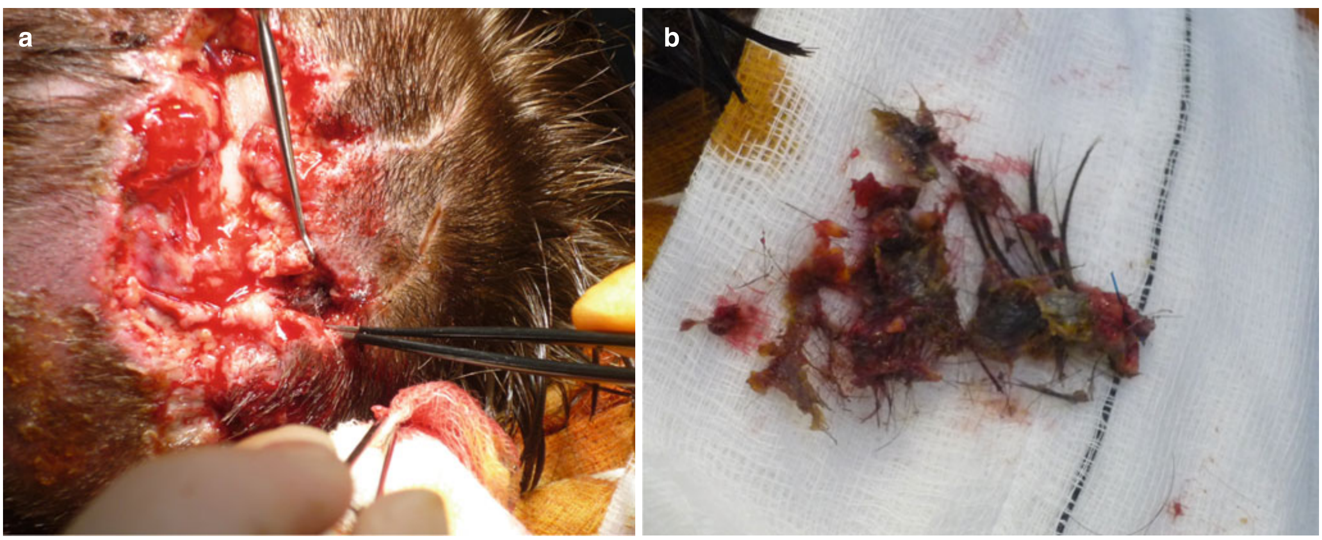

Fig. 14.94 Further exploration revealed hair, which had been trapped below the wound (**a**, **b**)

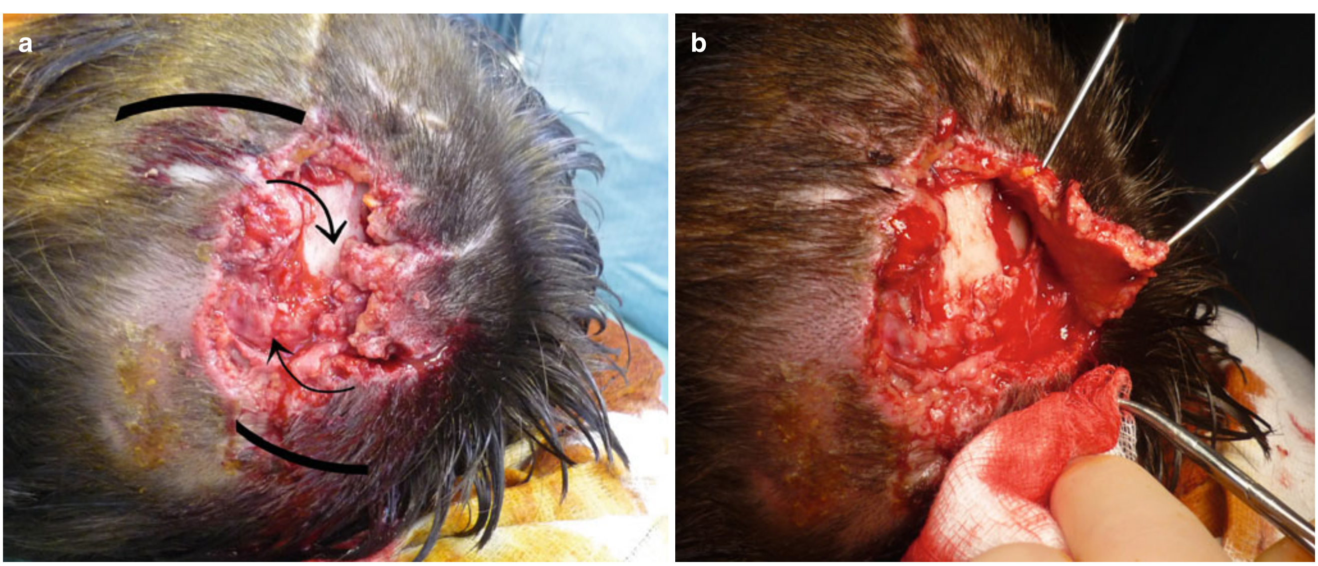

Fig. 14.95 Primary closure was not possible, so a two-layer (pericranium, scalp) “double hatchet” flap closure was planned. Note fracture is now visible (**a**, **b**)

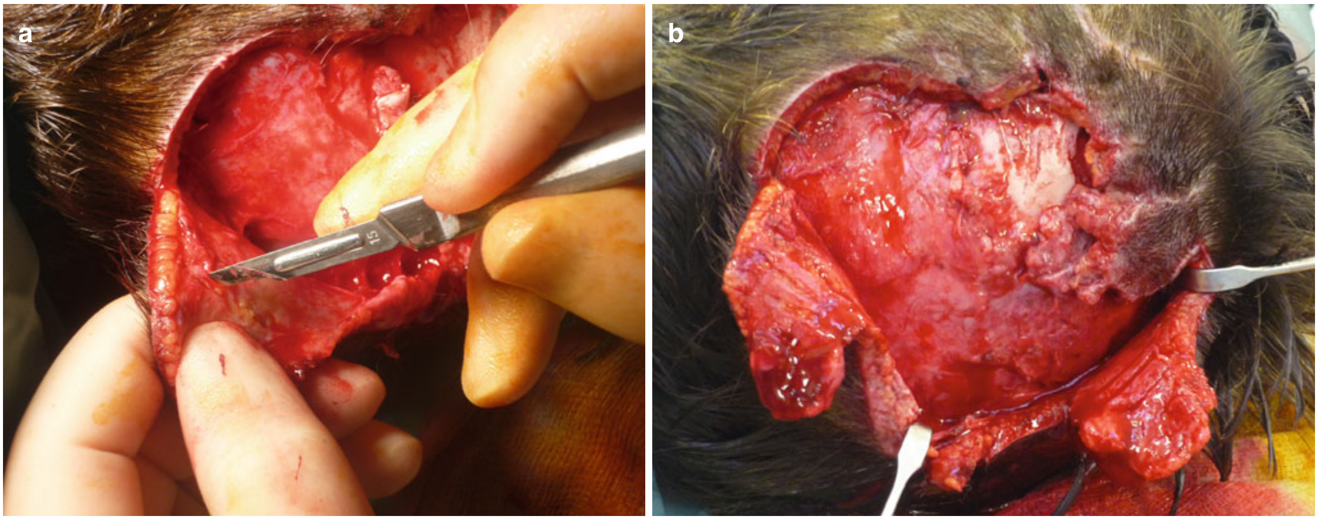

Fig. 14.96 To facilitate scalp closure, the aponeurosis was incised multiple times. This allowed the scalp to stretch a small amount (**a**, **b**)

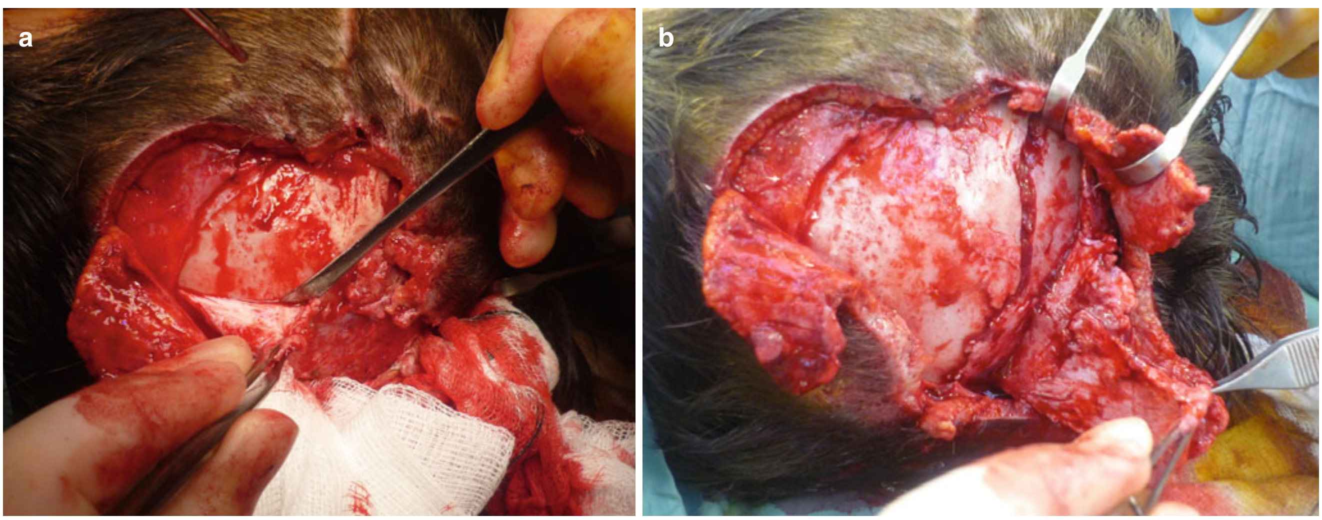

Fig. 14.97 The pericranium was widely mobilised to allow the fracture to be covered (**a**, **b**)

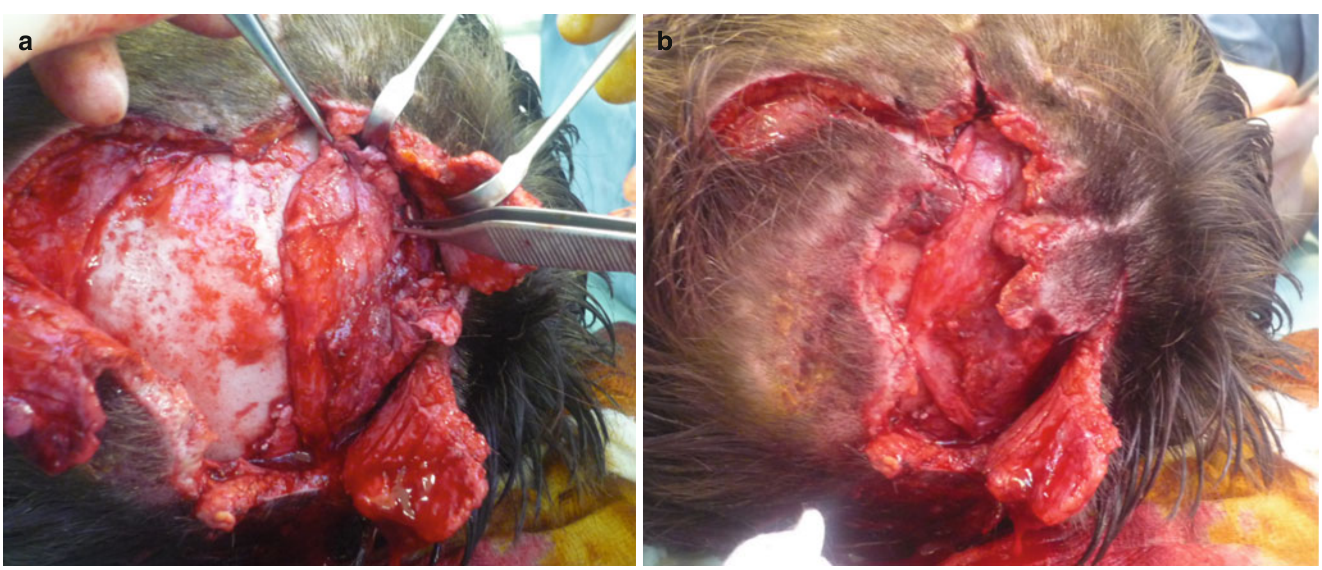

Fig. 14.98 Pericranium was rotated to cover the fracture and sutured in place (**a**, **b**)

Fig. 14.99 The scalp was then rotated to close the entire defect and closed in layers

Delayed primary closure may be necessary when doubt exists about the viability of a wound, or if it becomes infected. This is most likely to be the case following blast or high-impact injuries. Crushed tissues are especially difficult to manage. These may initially appear viable, but may later become necrotic. Multiple surgical procedures may be required. Split-thickness skin grafts may be used as a temporary measure if there is tissue loss, with revision surgery delayed until the patient has recovered or there are minimal risks of infection.

Case 4

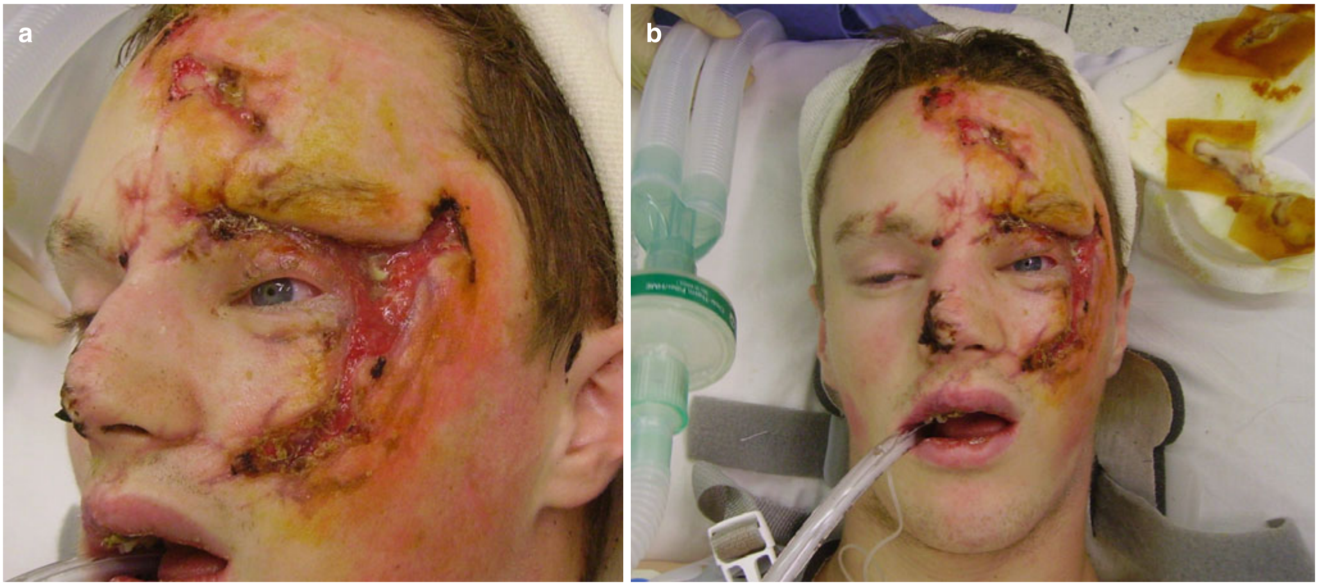

Fig. 14.100 Significant soft tissue injuries following ejection from a vehicle. Patient was too unstable for primary repair and was presented late (12 days) (**a**, **b**)

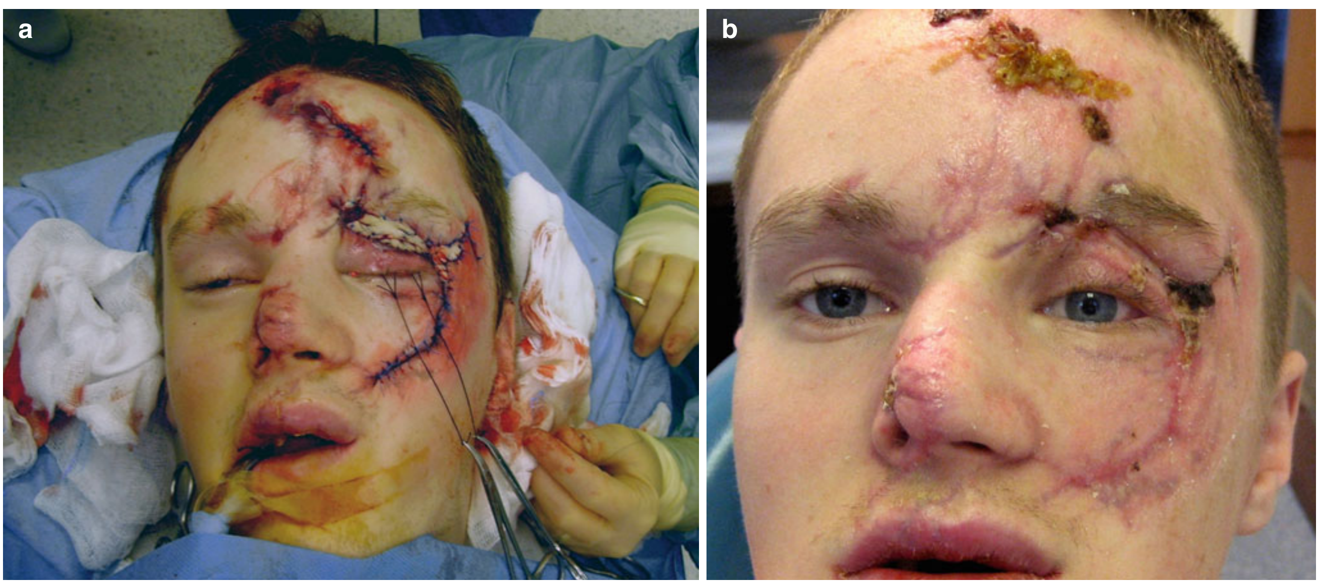

Fig. 14.101 Tissue had been lost from the upper eyelid. All tissues were friable and inflamed. Repair required debridement, delayed closure and use of a full-thickness skin graft (**a**, **b**)

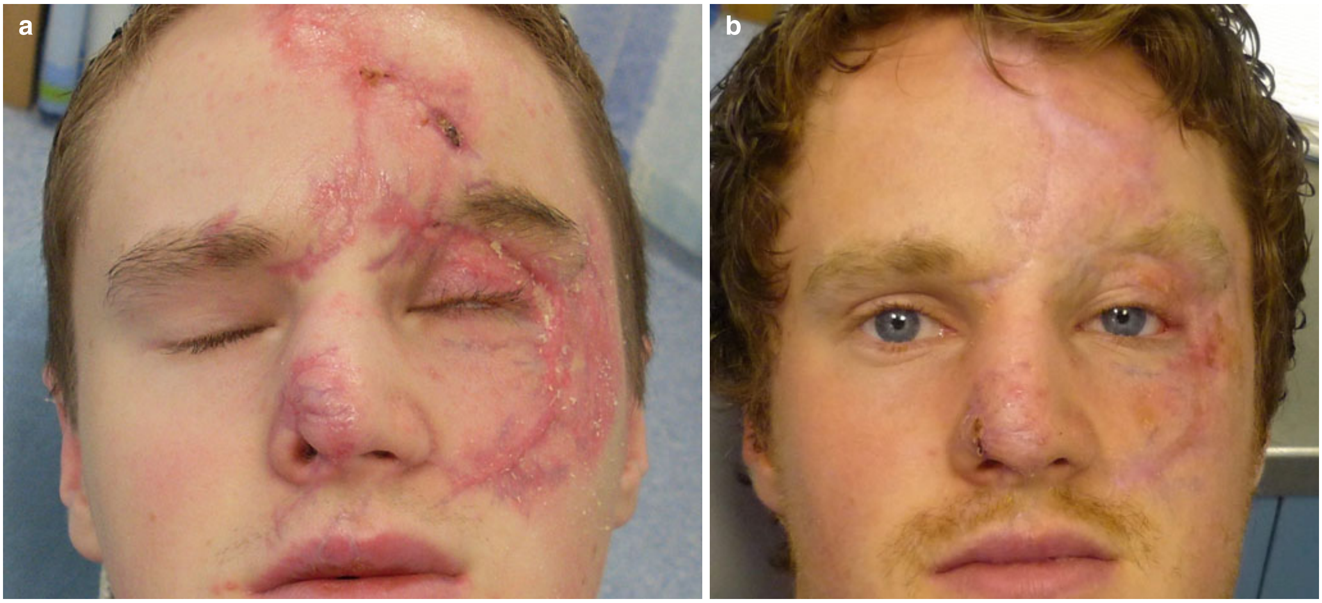

Fig. 14.102 Postoperative appearances at 3 months and 1 year. Intensive follow-up and aftercare was required (**a**, **b**)

When doubt exists about the status of a wound, it can be maintained with moist dressings, antiseptics and antibiotics for several days. This is useful in wounds with significant damage or heavy contamination, such as in crush or blast injuries. Dead tissue will then "declare itself" and can then be excised, allowing delayed primary closure. Following initial excision of obviously necrotic tissue, a nonadherent dressing is placed or the wound lightly packed. It is then inspected under sterile conditions a few days later. If there is no evidence of further necrosis or infection, it can then be closed.

Case 5

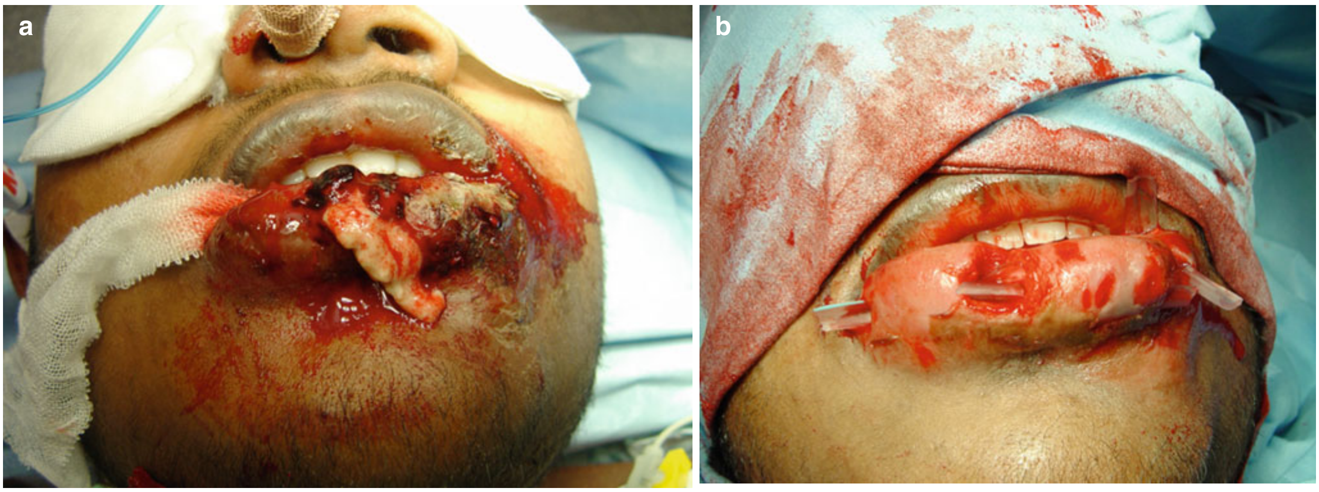

Fig. 14.103 Delayed presentation of a lacerated lip, following a bite. It is now infected. Following careful debridement drains have been placed (**a**, **b**)

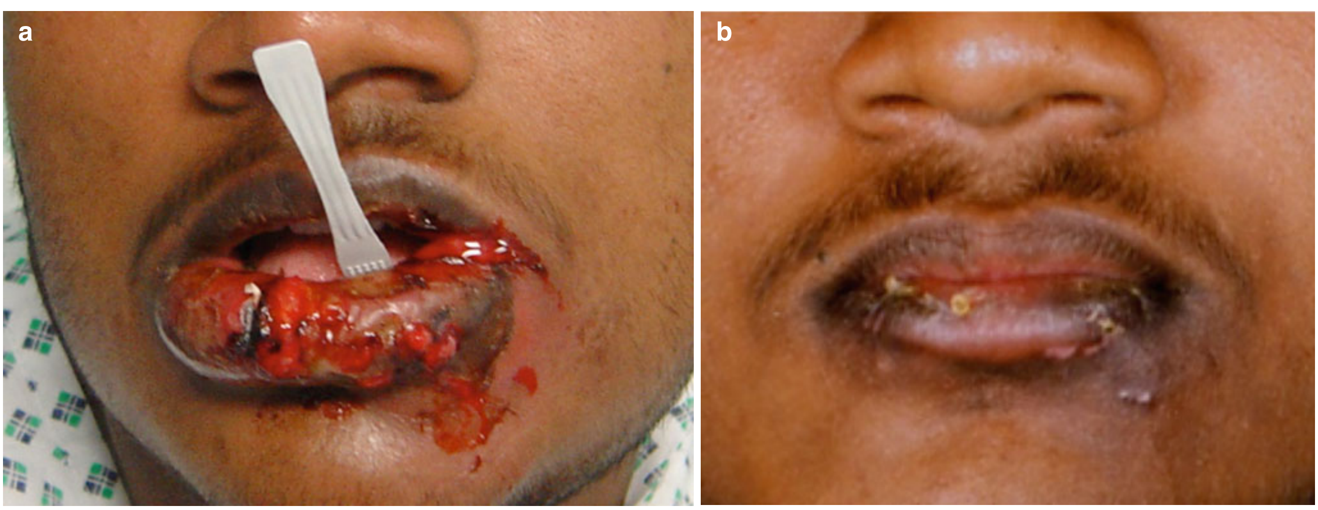

Fig. 14.104 Drains removed after 3 days (**a**) and results at 2 months (**b**)

On occasion, gross swelling may also preclude primary closure. In the case shown, excessive proptosis (from oedema) precluded closure of the wounds following repair of the fractures. Closure was not possible until a further 3 days had passed.

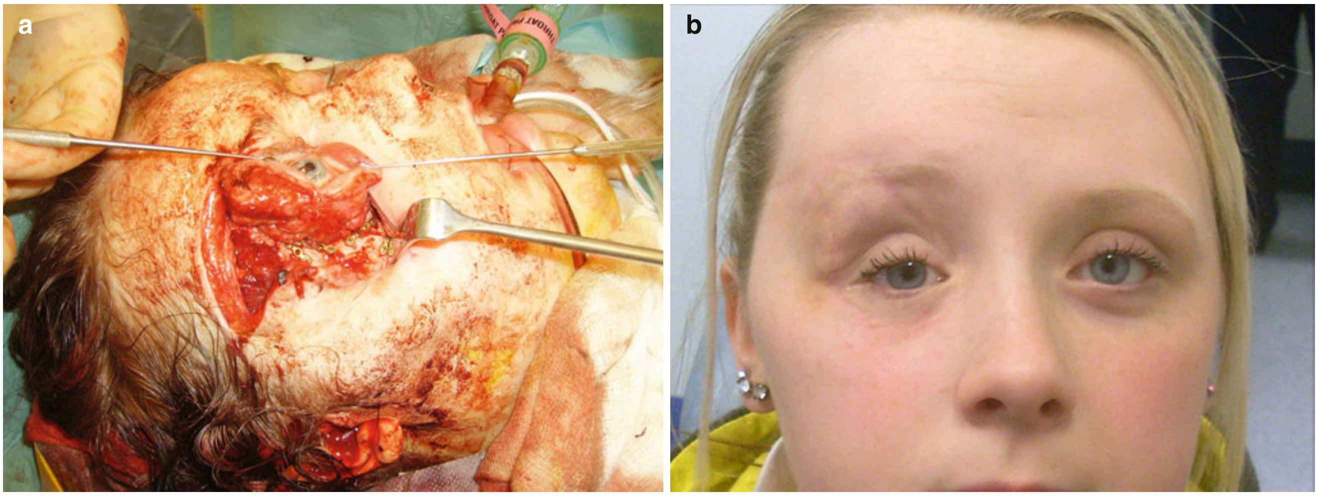

Fig. 14.105 This patient suffered extensive fractures and soft tissue injuries following a motor vehicle collision. Following repair there was significant proptosis and concerns regarding vision. The wound was therefore left for 3 days and closed as a planned procedure once the swelling had subsided (**a**, **b**)

14.6 Healing by Secondary Intention

Generally speaking, wounds tend to gape open, partly due to the elastic pull of the dermis. If not closed, the defect fills with a blood clot which then dries to form a scab. In small, uninfected wounds, re-epithelialisation begins around the wound edges, which then passes under the scab. The scab is gradually lifted away at its edges until it falls off.

Gaping wounds also heal from the base upwards. With larger wounds, granulation tissue can therefore be abundant. This results in a wide area of scar tissue formation, which can contract, resulting in significant deformity. The distinction between primary and secondary intention healing is just a quantitative one. The same mechanisms of wound healing are at play in both types.

Healing by secondary intention is generally best avoided in the face and neck, as the aesthetic results are usually very poor. If primary closure or flap rotation into the defect is not possible, then skin grafts are often placed on the wound bed to facilitate closure and minimise scarring. These are especially useful for small areas of tissue loss where local flaps will distort nearby structures.

14.7 Tissue Loss

This is relatively uncommon but may be seen following gunshots, industrial accidents and bites. More commonly, tissues are displaced, rather than lost. Occasionally, immediate replacement of the avulsed tissue (or immediate grafting) will result in a surprising degree of revascularisation and healing. This is only possible with small volumes of tissue. Partial loss of the nasal rim can be successfully grafted using part of the pinna.

Fig. 14.106 Loss of alar following a human bite. The missing piece was in a police evidence bag (!) and could not be salvaged. Repair was undertaken using a corresponding full-thickness graft from the pinna (**a**, **b**)

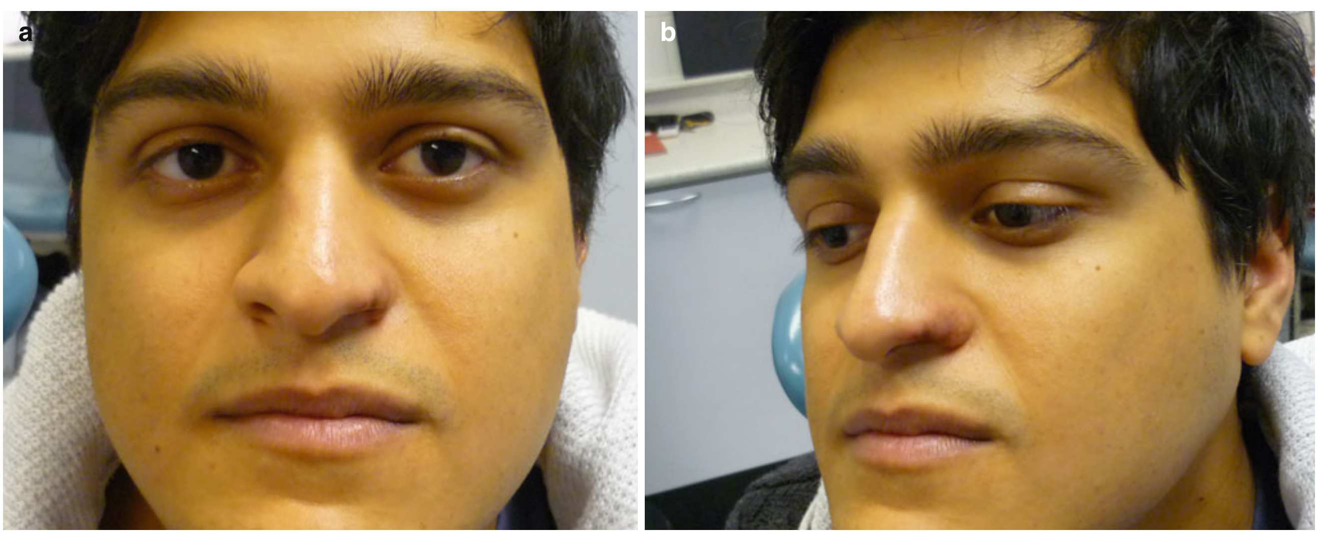

Fig. 14.107 Despite initial dusky appearances, these grafts have a reasonably good success rate (**a**, **b**)

Options for replacing lost tissue include:

1. Dress and allow to heal by secondary intention
2. Closure under a degree of tension
3. Immediate replacement of the avulsed tissue as a free graft
4. Immediate reconstruction of the defect with a free graft
5. Skin graft
6. Local flap
7. For avulsion of scalp/ear/nose injuries: refer for consideration of replantation using microsurgical techniques.

This list is sometimes referred to as the "reconstructive ladder."

Direct closure of a wound under tension may sometimes work. This relies on the skin's natural elasticity and ability to stretch (or "creep"). This approach often works well in elderly patients. However, wounds can break down, distort nearby structures or result in a stretched scar.

Where a small amount of skin has been lost, local flaps or skin grafts may be used to close or cover the defect. Full-thickness skin grafts contain epidermis and dermis, and provide a better cosmetic result than split thickness grafts, which are composed of epidermis and just a proportion of the underlying dermis. To ensure the best possible colour match, grafts should be harvested from the head and neck region, and certainly from above the level of the scapulae if possible.

Case 1

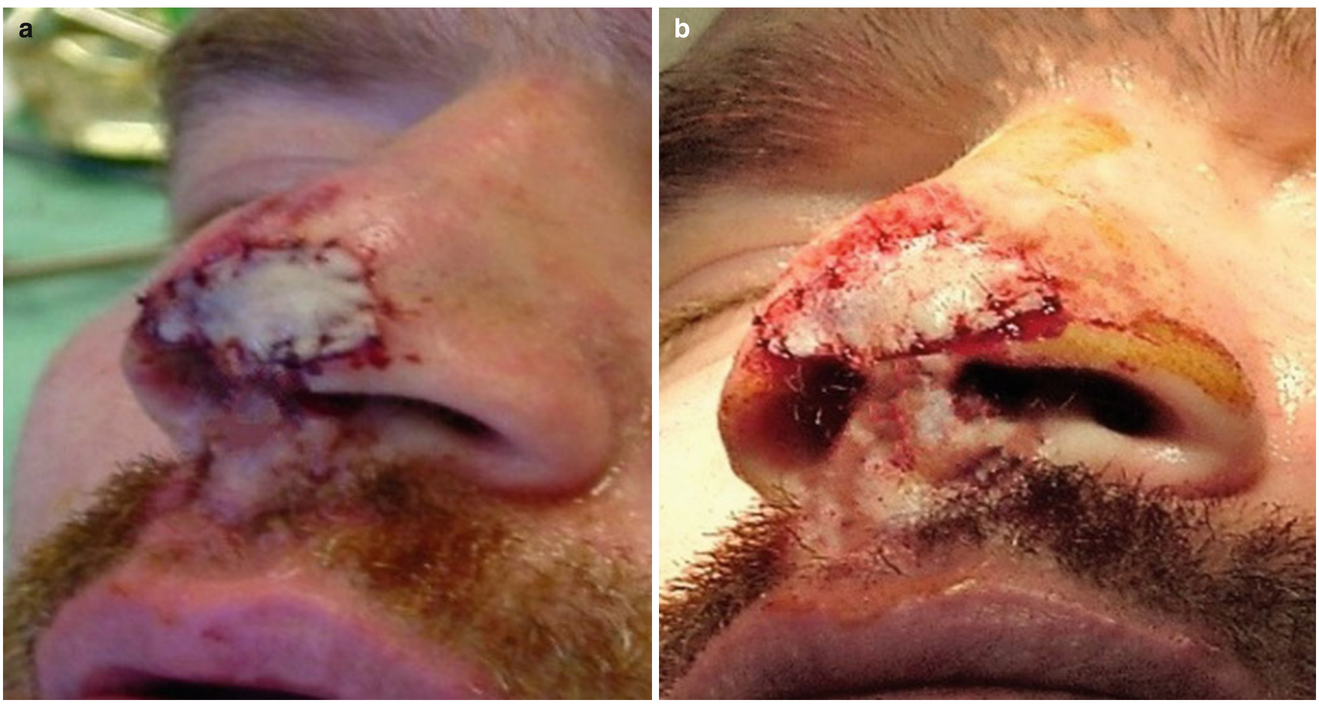

Fig. 14.108 Full-thickness skin graft to cover skin loss to tip of nose (following a fall). Alternatively, a local skin flap could have been used (**a**, **b**)

Fig. 14.109 Postoperative appearances at 4 months (**a**, **b**)

Case 2

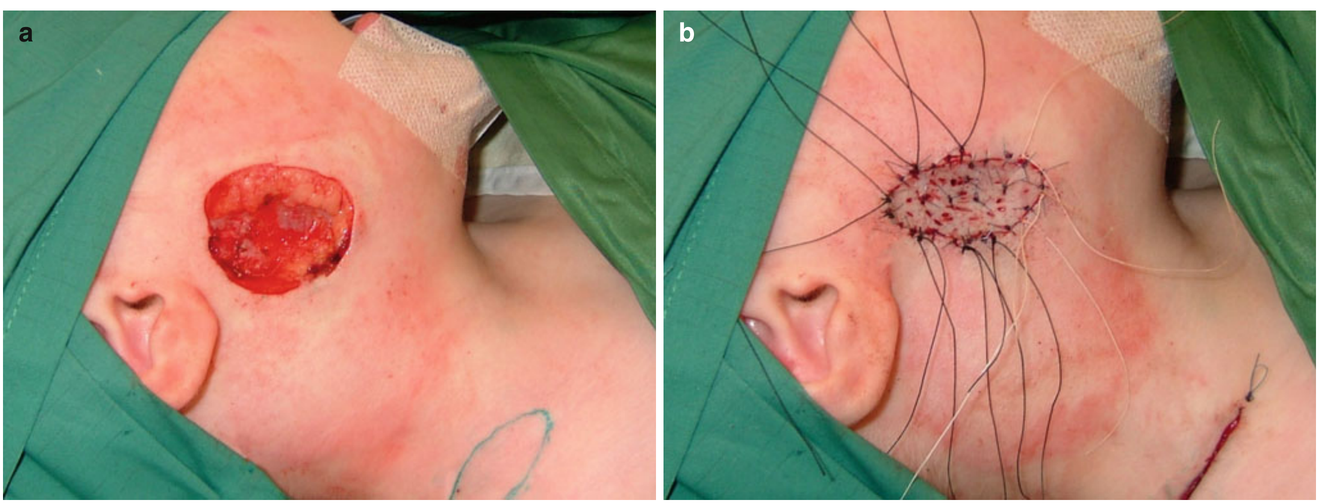

Fig. 14.110 Dog bite in a child, with loss of skin. Wound has been cleaned and minimally debrided. Surgeon has elected to place a full-thickness skin graft. A rotation flap is another alternative (**a**, **b**)

Numerous local flaps have been described in the literature and other text books. These make use of the fact that there is often a small amount of excess skin on the face which is highly vascular and elastic enough to allow undermining and the closure of nearby defects. "Random pattern" flaps rely on a nonspecific blood supply from the subdermal plexus. This generally limits flap design to a length-to-breadth ratio of no more than 3:1. "Axial pattern" flaps are designed on a recognised arteriovenous supply. Commonly used examples include the glabellar flap and nasolabial flap. These may be raised, based on a relatively narrow pedicle through which the vessels pass. As long as the vessels are preserved and are not kinked during rotation of the flap, large areas of skin can be used to close defects. In contrast with the remainder of the body, the skin of the head and neck is very well vascularised and the success rate of local flaps is generally very high. These techniques are particularly useful in the reconstruction of nasal tips, eyelids, and lips.

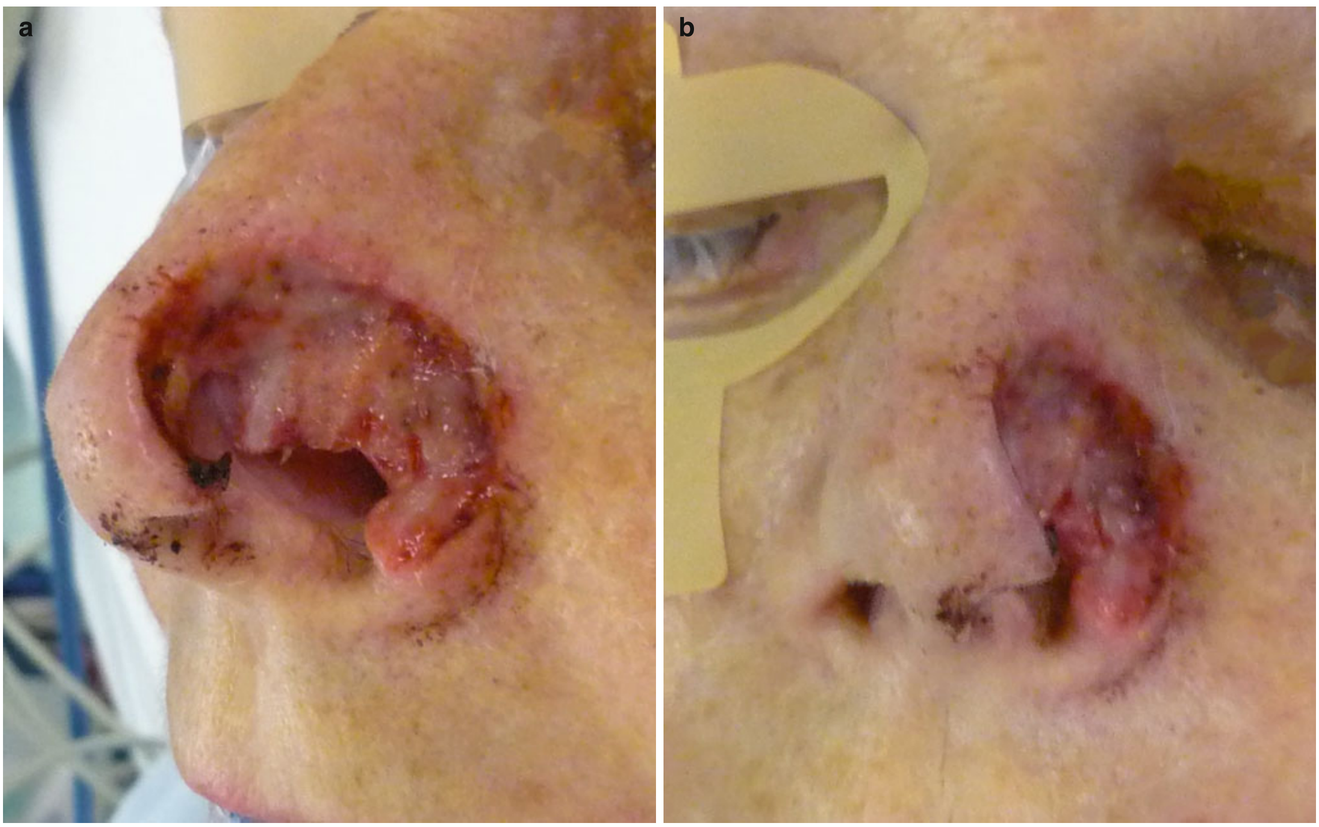

Fig. 14.111 Local flap reconstruction following dog bite to nose. Defect is defined following debridement (**a**, **b**). This can be reconstructed using a number of techniques

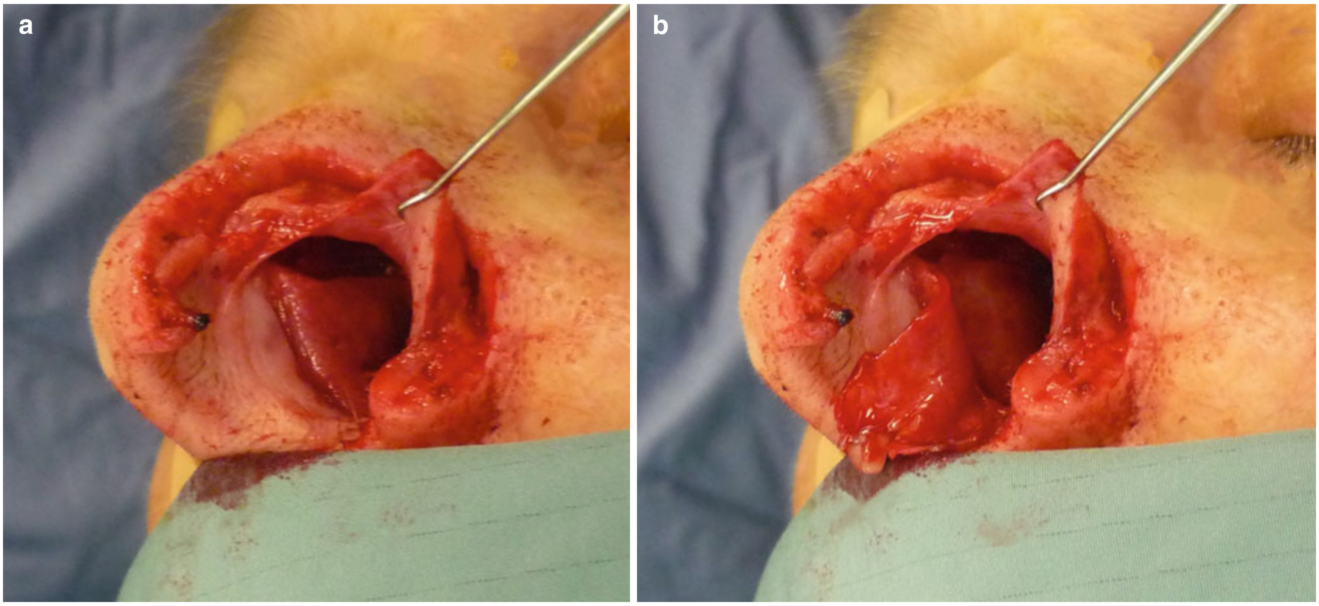

Fig. 14.112 In this case, the nasal mucosa was first reconstructed using a pedicled flap of septal mucosa (**a**, **b**)

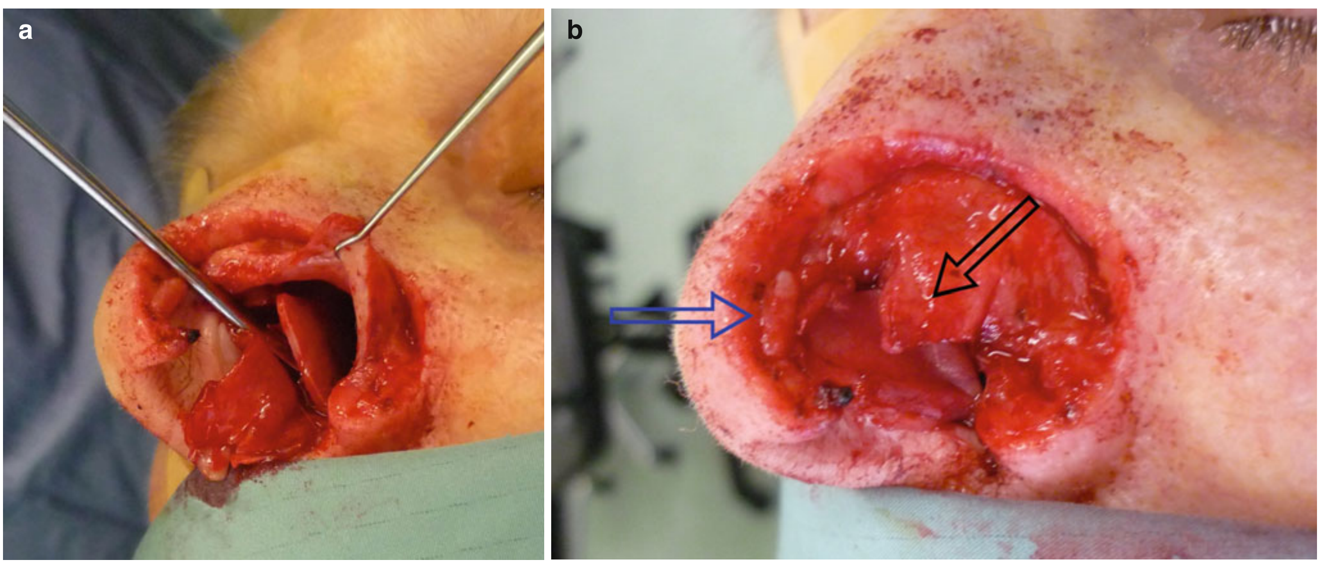

Fig. 14.113 Septal cartilage is harvested through the flap (**a**). This will be used later. The septal mucosa is sutured to the remaining nasal lining mucosa (*black arrow*) (**b**). *Blue arrow* shows remaining alar cartilage. The mucosal flaps seal off the nasal cavity and will need division later

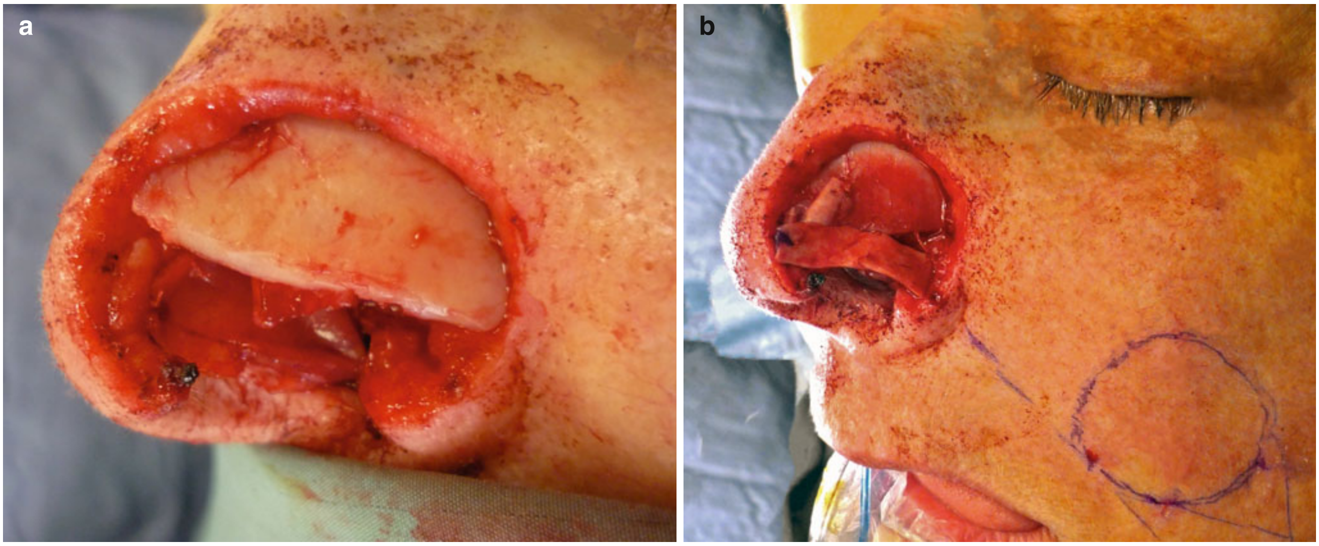

Fig. 14.114 Cartilage reconstruction uses thinned septum for upper lateral cartilage and pinna for alar cartilage. Note skin markings for pedicled flap (**a**, **b**)

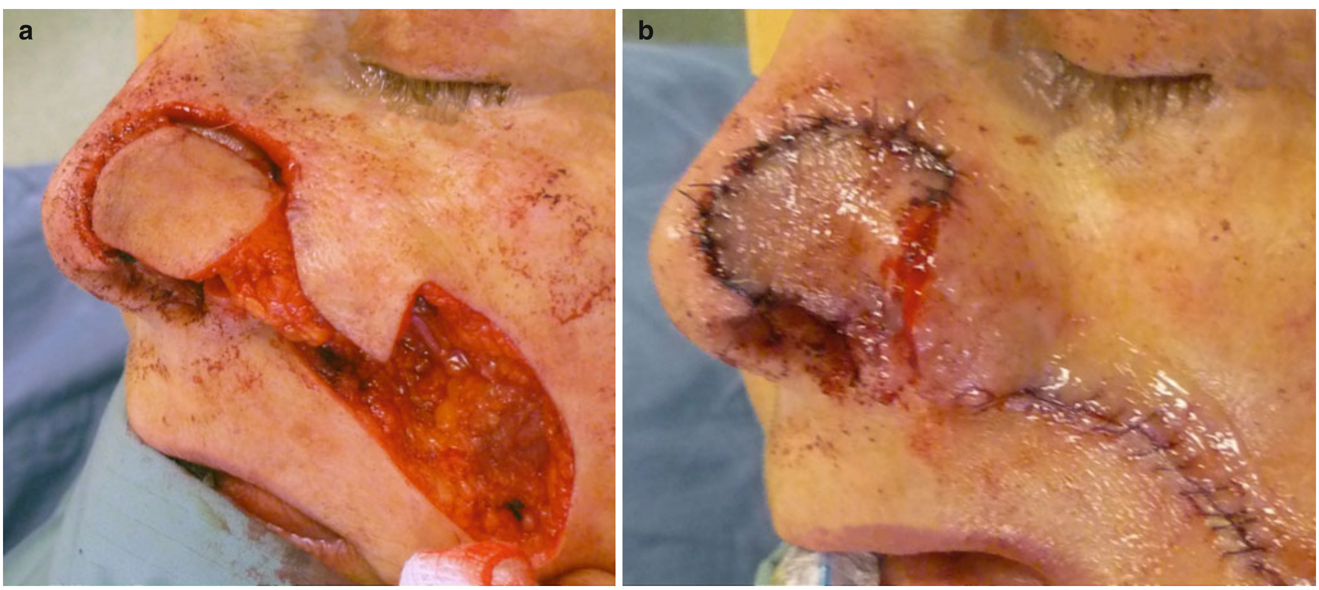

Fig. 14.115 The skin and subcutaneous tissues are reconstructed using a pedicled island flap. The pedicle is buried under the nasolabial skin following repositioning (**a**, **b**)

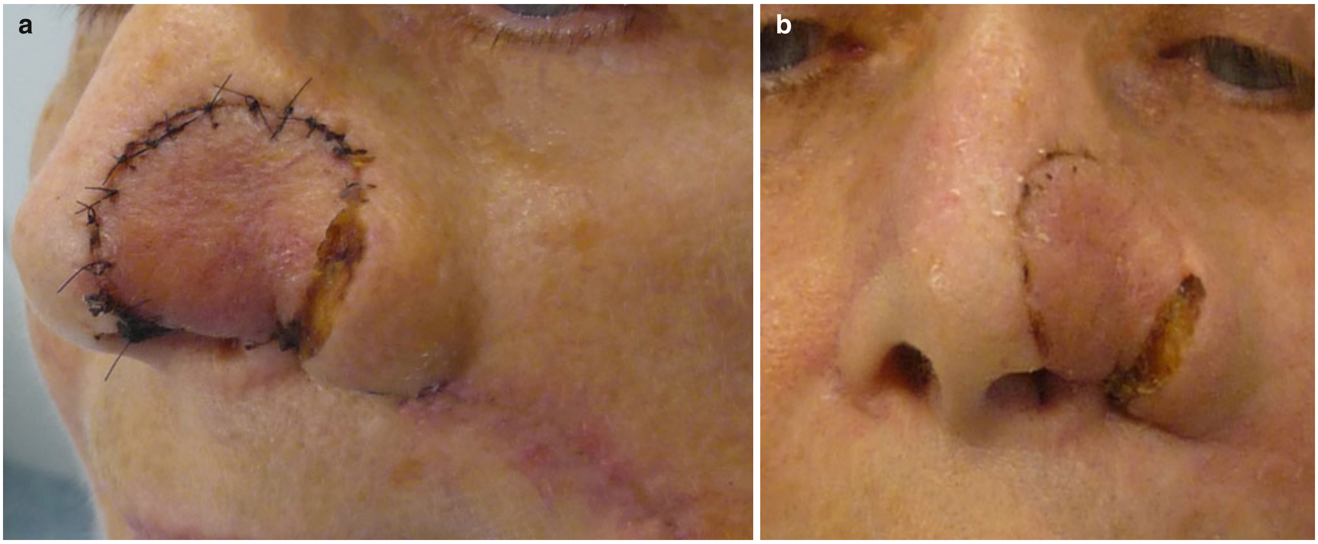

Fig. 14.116 Postoperative appearances at 3 weeks. The mucosal flap requires division (**a**, **b**)

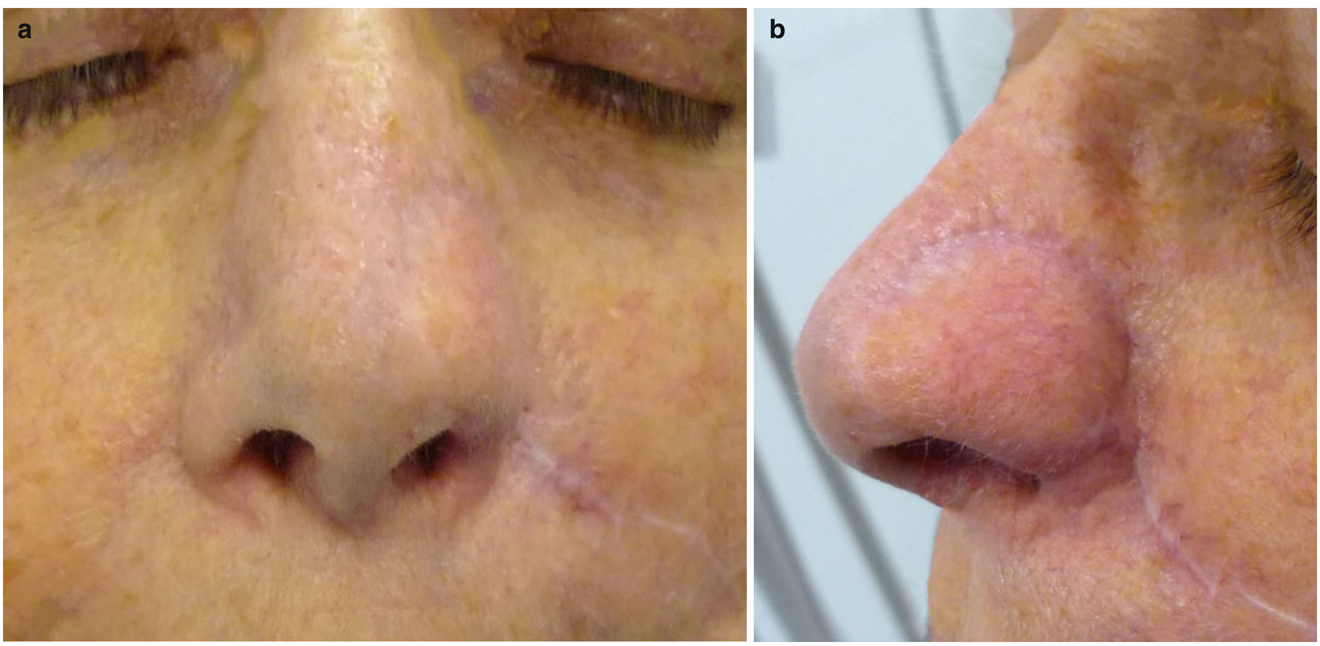

Fig. 14.117 Postoperative appearances at 9 months. The skin flap remains swollen for quite some time due to impaired lymphatic drainage. Thinning may be required (**a**, **b**)

Major tissue loss is uncommon but may arise following industrial injuries, blast injuries or pedestrian–motor vehicle collisions. Large defects (such as scalp or ear avulsions) can also be a combination of soft and hard tissue loss. These patients should be considered for replantation. The avulsed tissue should be washed in sterile saline or water and sealed in a plastic bag. This bag should then be placed in a suitable refrigerator. This will increase the tolerance to ischaemia. For transportation, the sealed bag containing the avulsed tissue may be placed into a second bag, containing a mixture of water and ice. Do not place the tissue onto ice alone as this can result in freezing of the tissue and reduce the likelihood of successful replantation.

In some cases it may be possible to replant the avulsed tissue and repair the arterial supply and venous outflow using microsurgical techniques. If the vessels can be identified and are in suitable condition, repair may be performed under magnification. The vessels may be directly anastomosed, or vein grafts may be required to bridge sections of damaged vessels. Such complex techniques require considerable surgical expertise to judge whether replantation should be attempted. Recent advances in our understanding of microvascular reconstructive techniques and in the technology of biomaterials now means that the vast majority of defects in the craniofacial region can be reconstructed one way or another.

14.8 Injuries to Specialised Tissues

14.8.1 Parotid Injuries

Lacerations along the side of the face must be carefully assessed to exclude injuries to the parotid gland, parotid duct and, most importantly, to the facial nerve. Injuries to the duct and nerve must be repaired before the skin is closed using microsurgical techniques. Failure to repair the duct may result in the formation of a sialocele, which will eventually drain cutaneously, resulting in a persistent and often troublesome salivary fistula. Where possible, the duct is repaired over a stent.

Failure to repair the facial nerve results in facial weakness. As a "rule of thumb," if facial weakness results from a laceration medial to a vertical line dropped perpendicularly from the lateral canthus, the nerve branches are usually regarded as too small to repair. Lateral to this line the cut nerve should be identified and repaired. Ideally repair should be undertaken as soon as possible and no later than 72 h, unless the wound is heavily contaminated (e.g., gunshot wounds). In this scenario, the nerve endings are tagged and repair is performed later when the wound is clean. Repair of damaged or severed nerves requires magnification. Either direct suturing of the divided ends or an interpositional nerve graft may be necessary, depending on the type of injury.

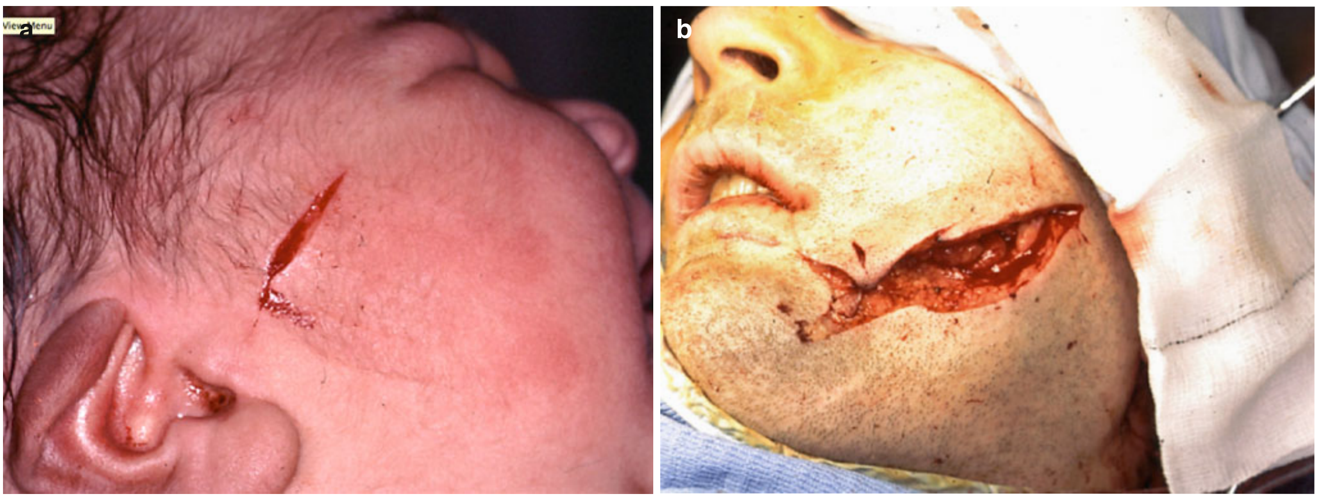

Fig. 14.118 Wounds to the side of the face can result in injuries to both the facial nerve and parotid gland/duct. These lay deep to the vessels, so beware if there is profuse bleeding (**a**, **b**)

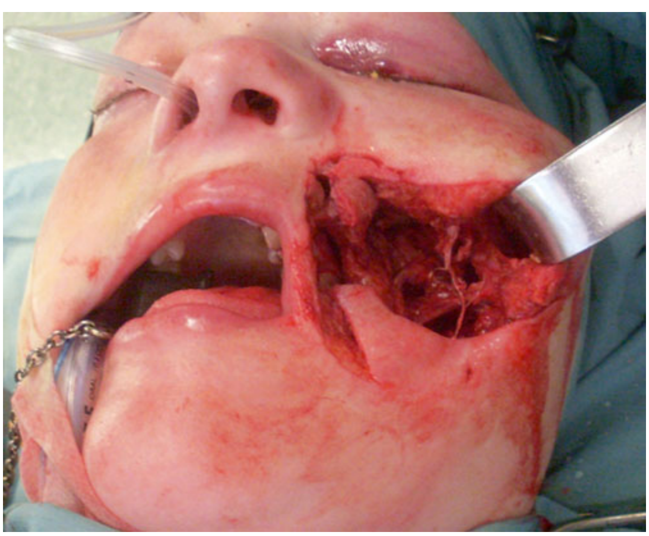

Fig. 14.119 Devastating injury following fall from a horse. There has been significant injury to the buccal and mandibular branches of the facial nerve. The parotid gland and duct have both been torn and there are associated fractures (**a**, **b**)

14.8.2 Microsurgical Nerve Repair

Good results have been obtained following reconstruction or repair of the accessory and facial nerves. However, reconstruction of sensory nerves has a lower success rate, although this may still be of benefit to the patient. Ideally early repair (within 24 h) is preferable and should be performed if there is no significant associated soft tissue trauma or infection. With the facial nerve recovery following late repair is limited by wasting of the facial muscles. This occurs around 6–12 months after injury. In long-standing cases of facial palsy with atrophy of the facial muscles, cross-facial nerve grafts and free tissue transfer or muscle flaps with their associated nerves and vessels have been used with some success.

Nerve injuries that may benefit from exploration are listed in Table 14.9.

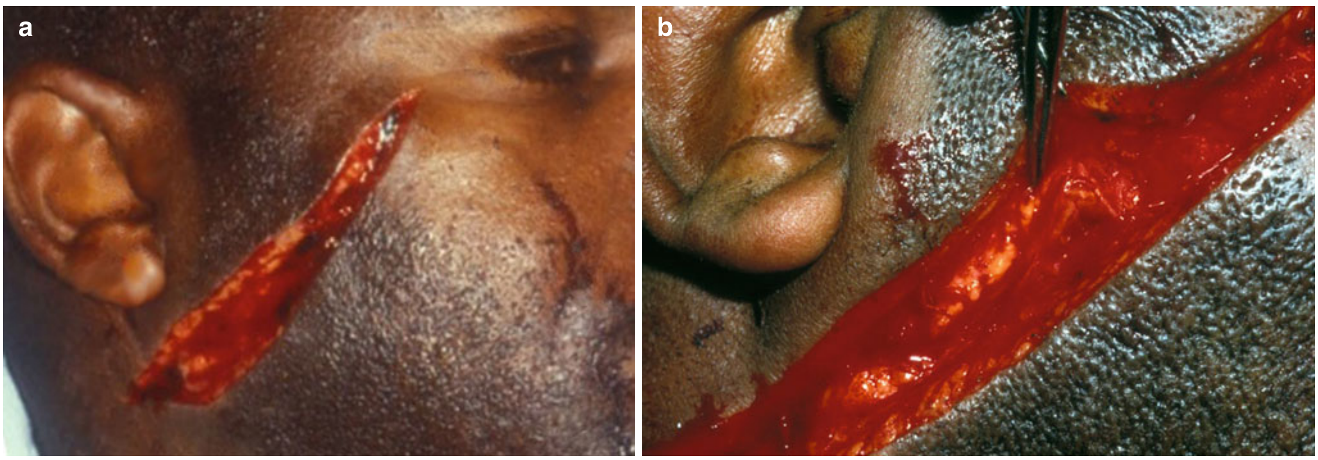

Fig. 14.120 Facial laceration with division of buccal branch of facial nerve (**a**, **b**)

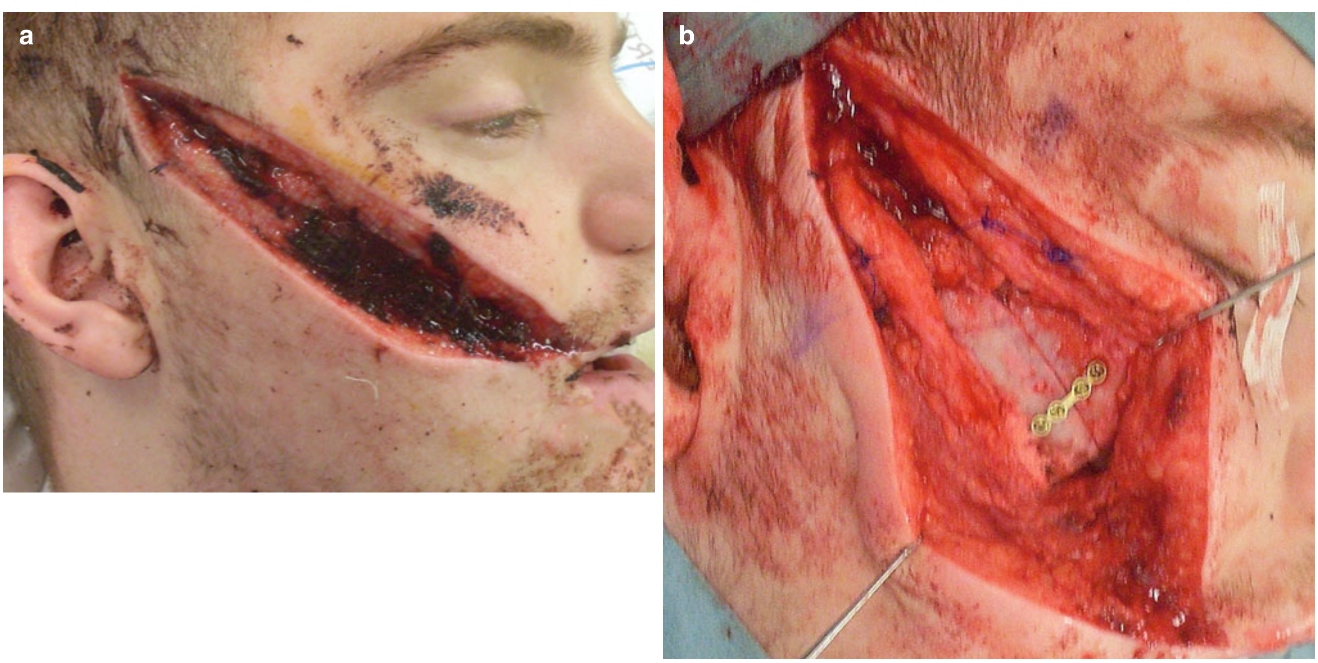

Fig. 14.121 Deep laceration through right side of face with underlying fracture (repaired). Branches of the facial nerve were initially identified and tagged (**a**, **b**)

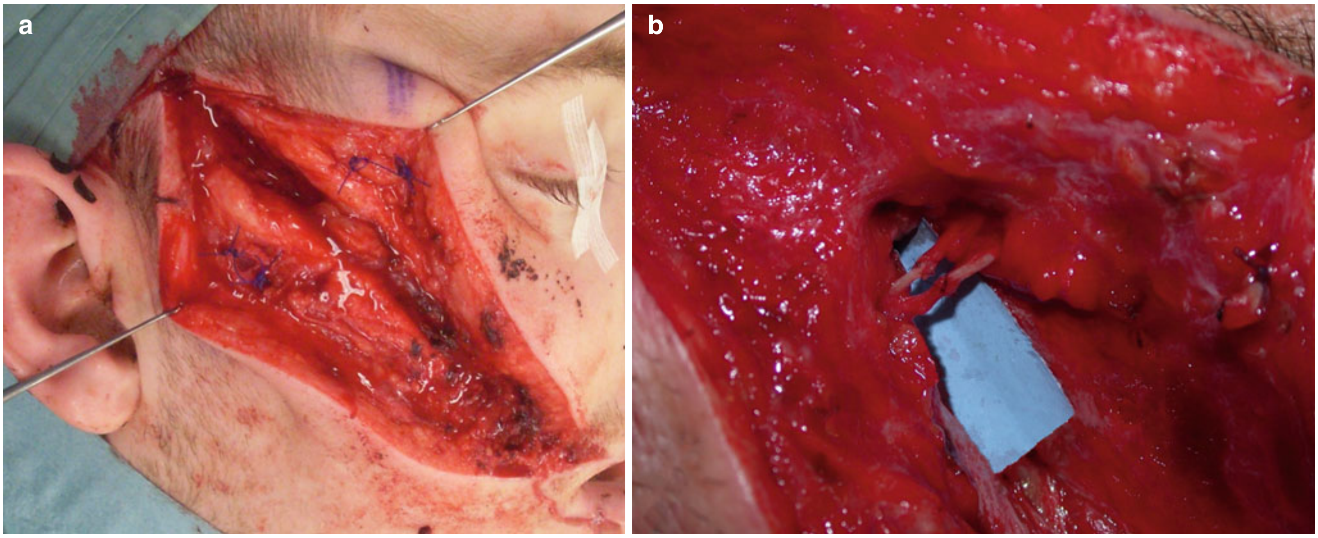

Fig. 14.122 Microsurgical repair of the two divided branches was required (**a**, **b**)

Table 14.9 Microsurgical nerve repair

Facial nerve: This may be damaged following trauma (or surgery) to the parotid region. If necessary, immediate repair can be delayed and the nerve endings marked with sutures
Accessory nerve: Injury to this nerve may occur following trauma (also following lymph node biopsies or neck dissection). Loss of function of the trapezius muscle results in limitation of shoulder motion
Inferior alveolar nerve: Injury may occur as a result of a mandibular fracture. It can also occur following wisdom tooth removal, osteotomy, tumour resection, fracture fixation, and placement of implants. This can result in numbness or dysaesthesia in the lower teeth, the lower lip, and the chin. Reconstruction should be undertaken within 3–4 weeks after injury
Since the facial and accessory nerve are purely motor nerves and the lingual and inferior alveolar nerves are mostly sensory nerves, repair is relatively straightforward in principle. The nerve stumps are aligned and an epineural repair undertaken. Alternatively the defect is excised and grafted. Manipulation of the nerves must be kept to a minimum as any additional scarring can prevent nerve growth. It is essential that there is no tension across the repair. The fewest number of sutures consistent with accurate alignment should be used. Where nerve grafting is required the great auricular and the sural nerve may be used, as they provide sufficient length with minimal donor site morbidity

14.8.3 Eyelid Lacerations

These require specialist care. Protection and assessment of the underlying globe is always the first priority (Table 14.10).

Loss of eyelid integrity is a vision-threatening injury, especially in the unconscious patient. This can compromise the cornea as it rapidly dries. While waiting for repair, the eyelid remnants should be pulled over to provide corneal protection (a traction suture may be required for this). Liberally apply Chloramphenicol or lubricant (ointment is better than drops) and cover the entire area with a damp gauze swab.

Simple eyelid lacerations can be explored and cleaned under local anaesthesia and then closed in layers. Care must be taken to ensure that the suture ends do not rub the cornea and cause abrasions. Superficial cuts can often be aligned with no sutures. They usually scab over and heal extremely well. Complex lacerations (such as those involving the lid margin, canthal regions, medial third of the lids and levator muscle) must be referred to a specialist for an opinion. These lacerations can disrupt the lacrimal drainage system and functional integrity of the lid and thus require detailed understanding of the functional and aesthetic anatomy of the region. As the lid is very vascular, even quite necrotic-looking tissue can survive and therefore no tissue should be excised. Good aesthetic and functional results can usually be achieved, but may require several procedures. Visual loss, unsightly scars and epiphora (watering) due to ectropion or obstruction of the tear outflow tract all commonly complicate eyelid lacerations.

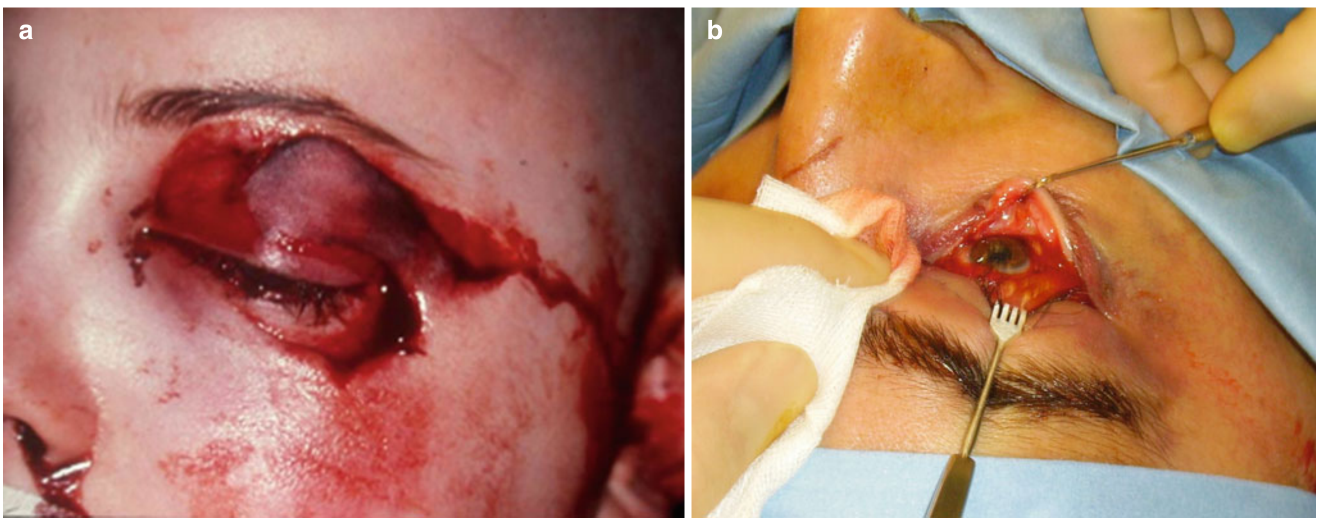

Fig. 14.123 Treat eyelid lacerations with extreme respect. These can be deceptively complex. Many require examination under anaesthesia (**a**, **b**)

Table 14.10

Eyelid lacerations Assessment and management of any associated ocular injury is more important than that of the eyelid. Conjunctival, corneal and scleral lacerations, hyphaema, lens dislocation, and globe rupture must all be excluded. Globe rupture and orbital fractures are likely with blunt injuries
Visual acuity, visual fields, colour vision, ocular movement, pupillary defect, and the fundus should be examined
Consider and examine for foreign bodies and perforating injuries. Avoid any pressure on the wounds
Small lid lacerations may conceal a large retained foreign body—use local or general anaesthesia to facilitate examination if required
Upper lid injuries may affect the levator muscle and its function should be noted. Plain orbital radiography may reveal fractures and retained foreign bodies, but CT scan is the investigation of choice if the history suggests a significant risk of FBs
Document your findings
As a temporary measure liberally apply chloromycetin ointment (not drops) to the wound
Refer for specialist assessment at an early stage

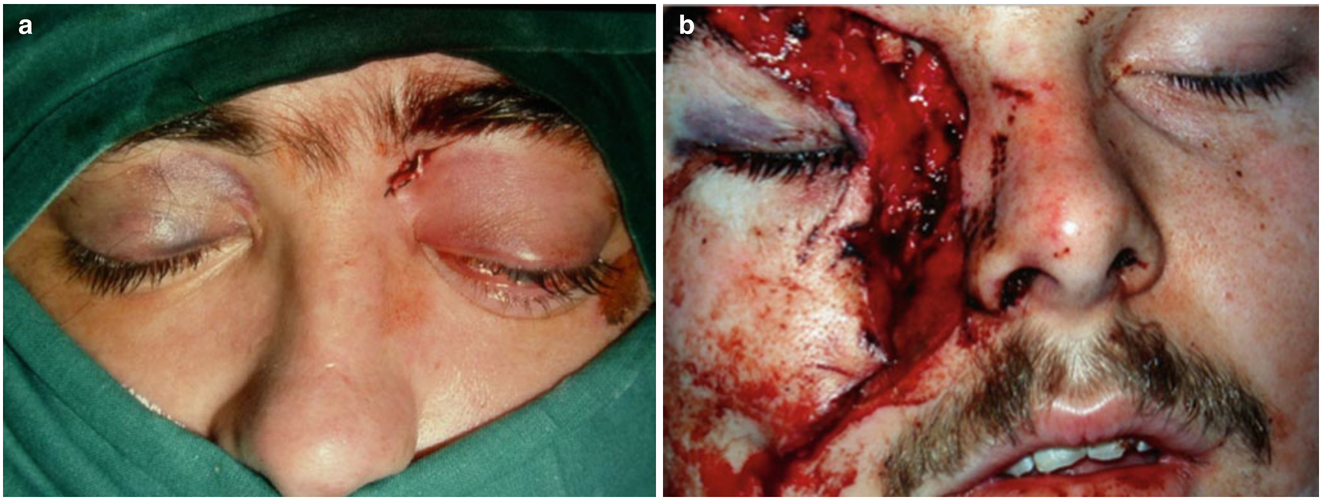

Fig. 14.124 The size of an eyelid laceration will give no indication of the risk to the eye and associated structures. The smaller of these two lacerations resulted in loss of sight, while the larger affected lacrimal drainage and canthal attachment but spared sight (**a**, **b**)

Fig. 14.125 Complex eyelid laceration involving medial canthal attachment and lacrimal system

14.9 Penetrating Injuries of the Neck

Penetrating injuries of the neck can be life-threatening and are managed by a number of specialists. Vascular surgeons are often involved. A number of important structures are at risk, especially when the injury is at the root of the neck. The neck is divided into zones:

- Zone I is located below the cricoid cartilage
- Zone II is between the cricoid cartilage and the angle of mandible
- Zone III is located above the angle of the mandible.

Depending on the clinical picture and the patient's condition, management varies. Ideally zone I and III injuries may be evaluated with CT or angiography prior to exploration as surgery is difficult and carries significant risks. Zone II injuries may require CT angiography, MRI angiography, oesophagoscopy, bronchoscopy, barium swallow, ultrasound scanning or angiography, depending on the injuries suspected. Comprehensive management falls outside the remit of this book, but many excellent texts and protocols on the subject exist.

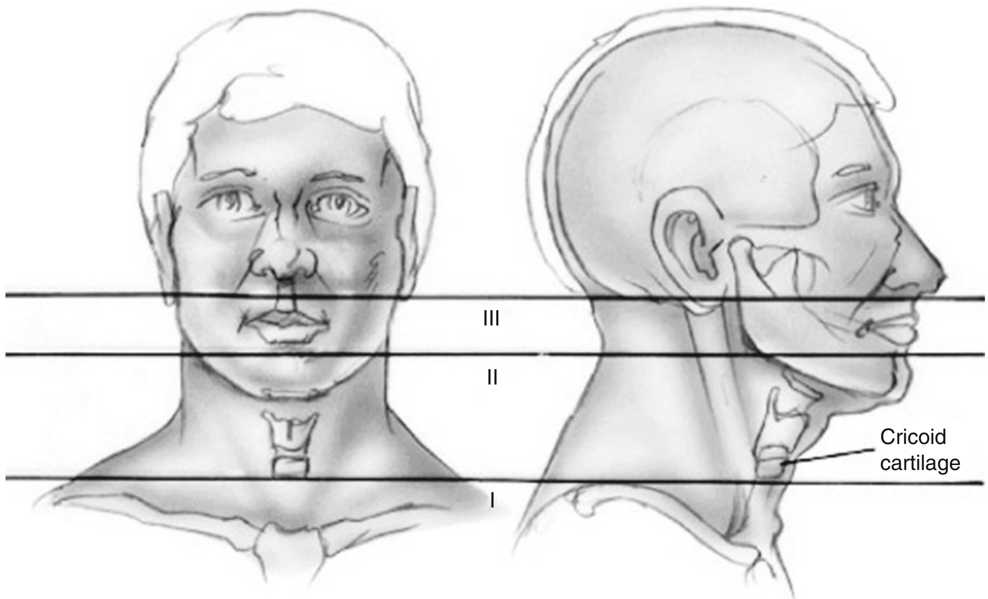

Fig. 14.126 Zones of the neck when assessing penetrating injuries

Fig. 14.127 Deep neck laceration. Facial nerve was intact (**a**, **b**)

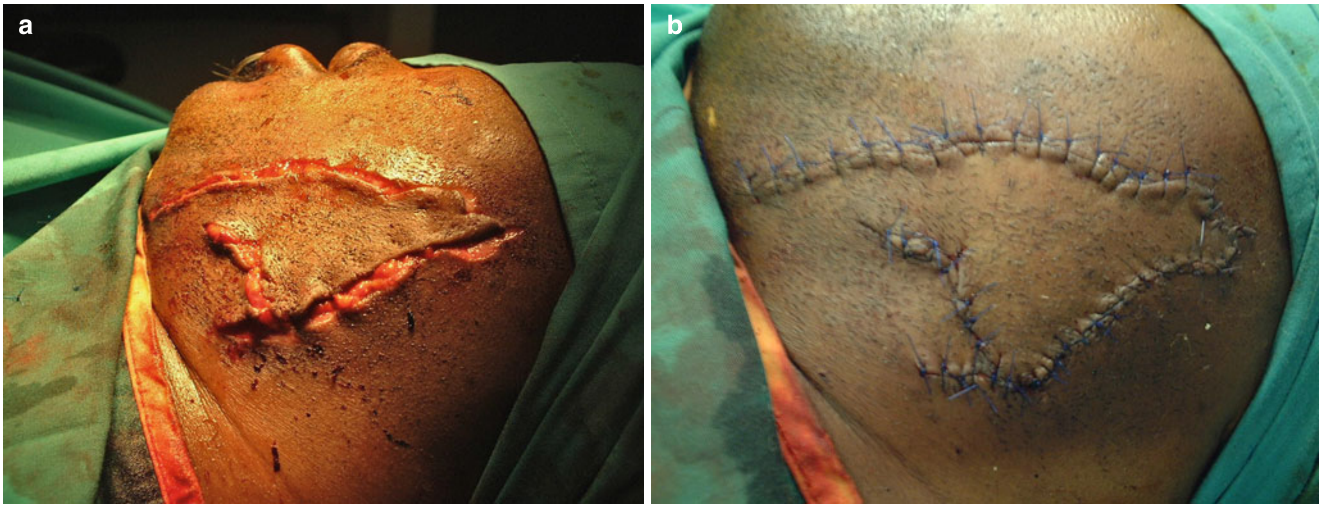

Fig. 14.128 Minimal skin trimming and closed in layers (**a**, **b**)

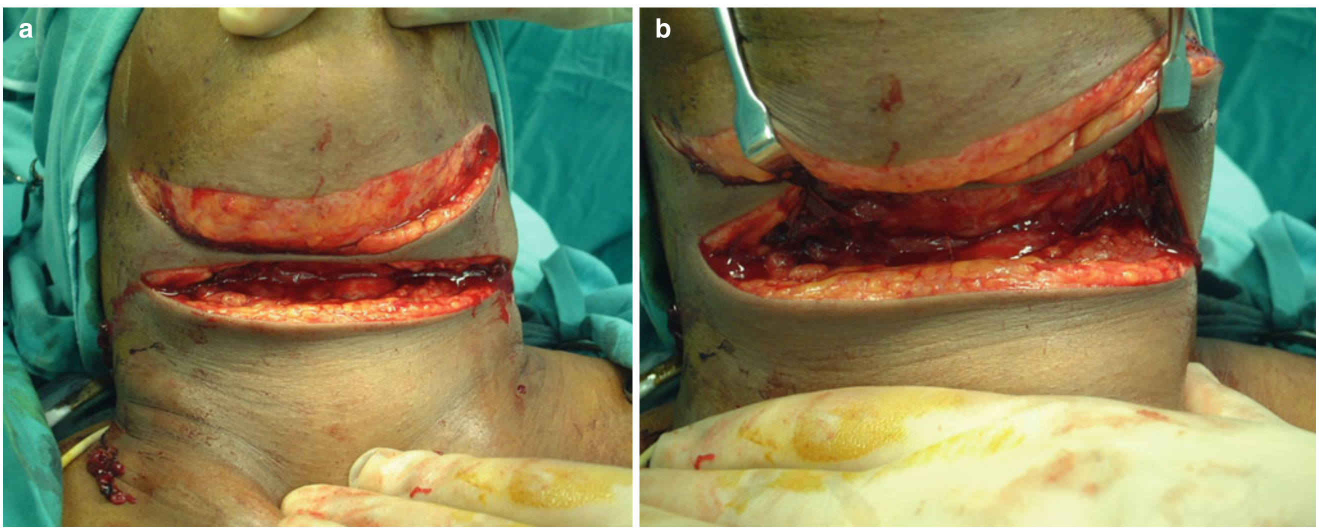

Fig. 14.129 Two clean parallel lacerations following an alleged assault. The underlying platysma had been incised. The intervening bridge of tissue was too narrow to repair (**a**, **b**)

Fig. 14.130 The wound was closed in layers following excision of skin bridge. The tracheostomy was secured due to risks of bleeding and swelling postoperatively

14.10 Dressings

Wounds need the correct environment to heal. Many factors are involved in wound healing and factors such as infection, poor nutrition and medical conditions, e.g., diabetes can delay healing. Smoking and previous radiotherapy to the site can have a major detrimental effect. Dressings are not required for every wound, but they can help to promote wound healing by providing the optimum conditions required for tissue repair.

Wounds heal more effectively in a moist, warm environment, which new-generation dressings now provide. Keeping tissues moist reduces pain, as exposed nerve endings do not dry. Cellular migration and phagocytosis is also facilitated and epithelial cells migrate easily, decreasing healing time.

It can take several hours for normal cell activity to return following a dressing change. It is therefore important to balance the number of dressing changes with the need to maintain wound hygiene. Historically some dressings have been changed up to 3 or 4 times a day—or even more frequently, in cases of debridement using hourly changes of saline-soaked dressings. However, too-frequent dressing changes could delay healing and can increase the risk of infection and cross-infection to other patients.

For simple wounds, which have been directly sutured, a supportive dressing such as adhesive paper strips can help to reduce tension on the wound, aiding healing and reducing pain.

Other wounds may benefit from the application of a simple dressing of petroleum-impregnated gauze or a nonadherent, silicone-coated dressing. Gauze padding will absorb wound exudate, and this can be secured with adhesive tape or crepe bandaging. Antibiotic ointments or antibiotic-impregnated dressings are useful in wounds that were originally heavily contaminated, or have become colonised during a prolonged period of healing, but do carry a risk of encouraging resistance. Other dressings contain factors that promote wound healing, such as silver. These are sometimes used in chronic wounds.

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15 Ballistic Injuries

Andrew Monaghan

Ballistic injuries to the face are uncommon in civilian practice, but the increased military activity in Iraq and Afghanistan, together with terrorist events has led to a number of cases being treated in centres throughout the UK.

Although the classic military ballistic injury is produced by the high-velocity round, the vast majority of cases today are from explosive devices, commonly the improvised explosive device (IED). Published data show that IEDs and other explosive devices accounted for 61 % of ballistic injuries in UK casualties injured in Afghanistan, with only 8 % being due to gunshot wounds. These mechanisms therefore differ from civilian causes of facial trauma in the amount of high-energy transfer to the tissues and the extent of contamination. The use of body armour has led to protection of the abdomen and torso, while the face, neck and limbs still remain relatively exposed. Consequently, patients injured by explosive devices often have multiple injuries, which can have a significant impact on their overall management plan and reconstructive options.

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15.1 Why Are Ballistic Injuries Different?

Blunt trauma to the facial skeleton tends to produce relatively predictable patterns of fracture. In the mandible, linear fractures occur, with comminution occurring only in high-energy injuries. In the maxilla, fractures follow the relatively common patterns, such as those described by Le Fort—often the higher the impact force, the higher the level of fracture. Furthermore, with most blunt trauma soft tissue loss and gross contamination is unusual.

In contrast, however, gunshot or shrapnel injuries transfer a lot of energy and blast effects deep into the tissues. Ballistic injuries differ from most other facial injuries, therefore, in a number of important respects (see Table 15.1 and Fig. 15.1).

Table 15.1 Key differences between ballistic and nonballistic injuries

Ballistic injuries are often dirty and heavily contaminated
There may be associated burns produced by the heat wave
With ballistic injuries there is often extensive soft tissue disruption and possible avulsion of tissue
Fractures do not follow the typical patterns seen in civilian injuries. They are often comminuted and may be associated with hard tissue loss
Transmission of the blast effect through the tissues may produce tissue damage distant form the injury

Fig. 15.1 Extensive soft tissue injury from blast. Note the charred facial hair due to heat exposure. A well-vascularised and relatively clean wound may be considered for closure after initial decontamination

15.2 Initial Assessment and Management

As in all polytrauma, management of the airway and rapid control of haemorrhage are the early priorities.

The commonest cause of early death in patients with ballistic injuries is airway compromise. Airway obstruction may result from a number of factors. Bilateral fractures or comminution of the anterior mandible may lead to loss of tongue support, while maxillary fractures can collapse and displace backwards and downwards along the skull base. Both scenarios carry a greater risk to the airway if the patient is supine. Coexisting head injury, alcohol or administration of opiates (either recreational or for pain relief) can compound the problem further. The airway can also be obstructed by foreign bodies, notably teeth, bone and prostheses (see Fig. 15.2). With the passage of time oedema will become an increasing problem.

All these factors may be exacerbated by a reduced level of consciousness or coexisting airway burns. Injury or bruising to the neck may indicate laryngeal damage.

When such injuries occur, a decision regarding the need for a surgical airway will be required quickly. Data from Vietnam reveals that 17 % of facial injuries required tracheostomy, while in a US level 1 trauma centre, 21 % required tracheostomy for civilian gunshot wounds. Throughout this airway management, cervical spine protection is mandatory.

Failure of a patient to respond to fluid resuscitation, in the absence of visible active bleeding, should alert the clinician to occult (hidden) bleeding elsewhere. Small penetrating injuries can be easily overlooked. They can also be a significant distance from a site where major internal haemorrhage is actually occurring. A thorough examination of the entire body surface and immediate imaging of the large body cavities is therefore necessary in these "nonresponders" (to fluid challenge).

External bleeding can normally be controlled by packing or haemostasis of vessels in the area. Where bone fragments are widely displaced, these should be reduced and temporarily stabilised. Penetrating neck injuries may require neck access and ligation or repair of major vessels. Very occasionally penetrating vessel injury in the upper part of the neck (often referred to as "level 3") may require an osteotomy of the mandibular ramus for adequate access (see Fig. 15.3).

It is also important to be aware that ocular and ear injuries are commonly seen in ballistic injuries and can be easily overlooked. Bilateral orbital blow-out fractures have been reported in victims of blast injury, including cases where there has been no direct impact on the globe or surrounding orbital rim.

Fig. 15.2 Large metallic shrapnel fragment at the skull base producing airway obstruction

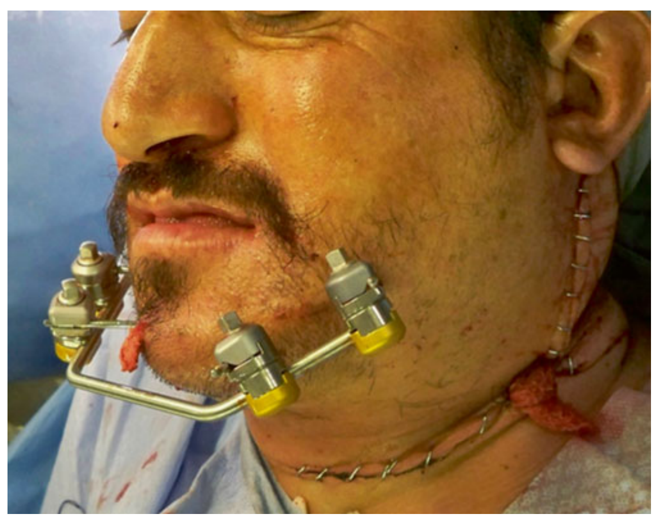

Fig. 15.3 The use of a proprietary wrist fixator (Hoffman 11 Compact, Stryker) for fixation of a comminuted fracture of the mandible. Note the neck access to control bleeding from the jugular vein which required ligation. The rifle round entered at the mandibular symphysis and exited the left neck

15.2.1 Initial Management of Ballistic Injuries

It is well recognised from historical records from previous conflicts that wound debridement and decontamination is the foundation of successful outcome in these cases. Failure to do this will result in poor outcomes despite the use of the most sophisticated forms of reconstruction. It was also recognised as early as the U.S. Civil War that it was not necessary to aggressively débride all damaged tissues in the face. If tissue can be retained it should be and revisited a day or so later to check its vitality. Such a conservative approach would not be possible in other parts of the body.

Prior to treatment it is essential to have a thorough appreciation of the extent of the tissue damage. Today imaging should include computed tomography (CT) scanning and three-dimensional (3D) reconstruction, together with any relevant models. It is also important to know the location of any rounds or projectiles which are still present within the tissues. Identifying their track through the tissues from the point of entry gives an indication about which structures could have been damaged en route.

General management of the wound forms the mainstay of successful treatment (see Table 15.2).

Heavily contaminated wounds may require serial debridement and packing. However, experience has shown that in the maxillofacial region, because of its excellent blood supply, early definitive soft tissue closure may be undertaken in less contaminated wounds. This requires careful judgement. Any soft tissue primary closure should be tension free and if uncertainty exists about the tissues, drainage should be instituted.

In some cases early reconstruction may be undertaken following wound debridement and decontamination. However, where there is any doubt about the viability of tissues it is better to wait 48 h for nonvital tissue to declare itself. This is sometimes referred to as a 'watch and wait policy.' The case shown demonstrates the management of a contaminated facial wound in an infant where definitive closure and fixation was delayed following thorough cleaning to ensure tissues were in the optimum state (see Figs. 15.4, 15.5, 15.6 and 15.7).

Table 15.2 Management principles in ballistic injuries

Thorough irrigation of contaminated tissues
Soft tissues with dirty wound edges should be gently but thoroughly scrubbed to prevent tattooing. Foreign bodies (if accessible) and detached bone fragments and teeth should be removed
If possible, periosteal stripping should not be undertaken
Identify and mark important structures such as branches of the facial nerve and the salivary ducts. These can be repaired later
Although antibiotic therapy is important, it is no substitute for thorough mechanical cleaning
Tissue defects can be temporarily packed

Fig. 15.4 An infant with a heavily contaminated fragment injury of the face. The early priority in this case is to decontaminate the wound prior to any consideration of definitive treatment

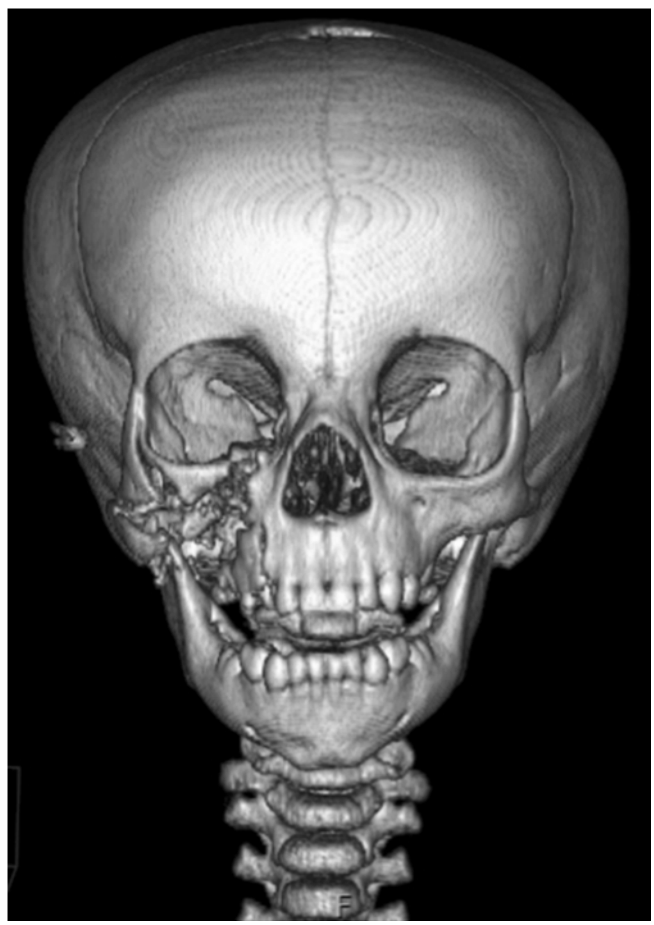

Fig. 15.5 CT scan showing the bony injury. Note the vertical split in the body of the zygoma

In cases where delayed definitive treatment is undertaken, temporary stabilisation of the bone fragments by a combination of interdental wiring, intermaxillary fixation (IMF) screws, conventional IMF, and external fixation will improve the patient's pain control and maintain alignment of the main fragments until definitive fixation is undertaken.

Fig. 15.6 Closure of the soft tissue wound 48 h after initial cleaning and dressing. Note that despite the initial appearance soft tissue loss is not extensive

Fig. 15.7 Radiograph showing the completed fixation

15.3 Repair of Ballistic Injuries

Contemporary management of maxillofacial injuries is based on the techniques of open reduction and internal fixation discussed elsewhere in this book. Those principles relating specifically to the management of ballistic trauma will be discussed further. It has previously been suggested that all fixation will eventually fail and that fracture healing is 'a race between bone healing and fixation failure.' We must, therefore, use fixation that provides 'adequate stability,' without overengineering and compromising healing.

Successful repair or reconstruction depends on the thorough understanding and appreciation of the increased damage to the hard and soft tissues, compared with conventional blunt trauma. Where fractures are comminuted, or involve loss of bone, or do not follow conventional fracture patterns, miniplate osteosynthesis is more likely to fail. This is because the typical tension and compression lines (described by Champey and others) are not present and the bone itself is unable to support any loading (referred to as "load sharing"). Consequently, in the early stages of healing all the displacing forces across the fracture site have to be supported entirely by the plates ("load bearing"). More substantial internal fixation should therefore be used. This typically involves the use of heavier plates. The authors' preference is for locking plates as these are reported to have a greater ability to withstand increased loading. However, the surgeon needs to be versatile in the approach, utilising other forms of fixation such as lag and positional screws as required.

Sequencing the repair of facial fractures is discussed in other parts of this book. The aim is to reconstruct the face in three dimensions, producing the correct height, width and projection of the facial skeleton with particular care to correct the orbital volume, dental occlusion and canthal position.

A sequence illustrating the management of a complex ballistic injury treated by wound debridement, second look and subsequent definitive open reduction and internal fixation 48 h later, is shown in Figs. 15.8–15.13.

Fig. 15.8 Extensive injury from high-velocity round. Note the small entry wound and large exit. The wound comprises both hard and soft tissue injury

Fig. 15.9 CT scan showing extent of bony injury

Fig. 15.10 Appearance after initial debridement and soft tissue repositioning. Note how nonviable areas are becoming perfused, enabling an improved decision on what tissues can be retained

Fig. 15.11 Fixation of the fracture with combination of load-bearing and load-sharing fixation

Fig. 15.12 Radiograph of injury treated by open reduction and internal fixation. Note the combination of locking reconstruction plate, miniplate and lag screw utilized to attain optimum stability

Fig. 15.13 Patient 2 months later showing reasonable cosmetic result

In some cases, an excessive degree of periosteal stripping would be required in order to securely plate some of the fragments. This risks devitalisation of small or comminuted fragments and their subsequent loss. In addition, any extended surgical access required would produce further trauma and scarring in already damaged tissues. In such cases, the use of IMF and external fixation can prove an effective and relatively simple way of treating these injuries definitively.

Experience has shown there is still a place for these techniques in the early stages of care prior to definitive treatment. The basic principle of external fixation involves the insertion of transosseous pins either side of a fracture and connection with a rigid rod. Two pins are required on either side of the fracture and in any major fragments for optimum stability. With external fixation, extensive periosteal stripping of viable fragments is not required. It is therefore a useful technique which can retain bone where viability is tenuous. Rods can span multiple fragments and with sufficient pins this provides load bearing fixation.

External fixation systems specifically designed for the maxillofacial region are available. However, if necessary other similar products can be used to achieve the same outcome. The case shown demonstrates a proprietary metal external fixator used to stabilise a comminuted mandibular fracture (see Figs. 15.14, 15.15, 15.16 and 15.17).

Fixators specifically designed for the maxillofacial region are available and some are composed of titanium rather than steel. This has the advantage of enabling magnetic resonance imaging (MRI) scans to be undertaken if required. The case shown shows how an external fixator can be made using easily available materials.

15.3.1 Management of Tissue Loss

Management of tissue loss can be extremely challenging. If bony union is to be successful there has to be adequate bone to bone contact and viable soft tissue coverage. The options to replace lost "hard" tissues (bone) are to use autogenous or alloplastic materials, or sometimes a combination of the two. In head and neck cancer surgery, much experience has been gained in microvascular free tissue transfer in the reconstruction of posterior sited defects following resection. Flaps such as the radial forearm, lateral thigh, fibula, deep circumflex iliac artery (DCIA) and scapula form part of the

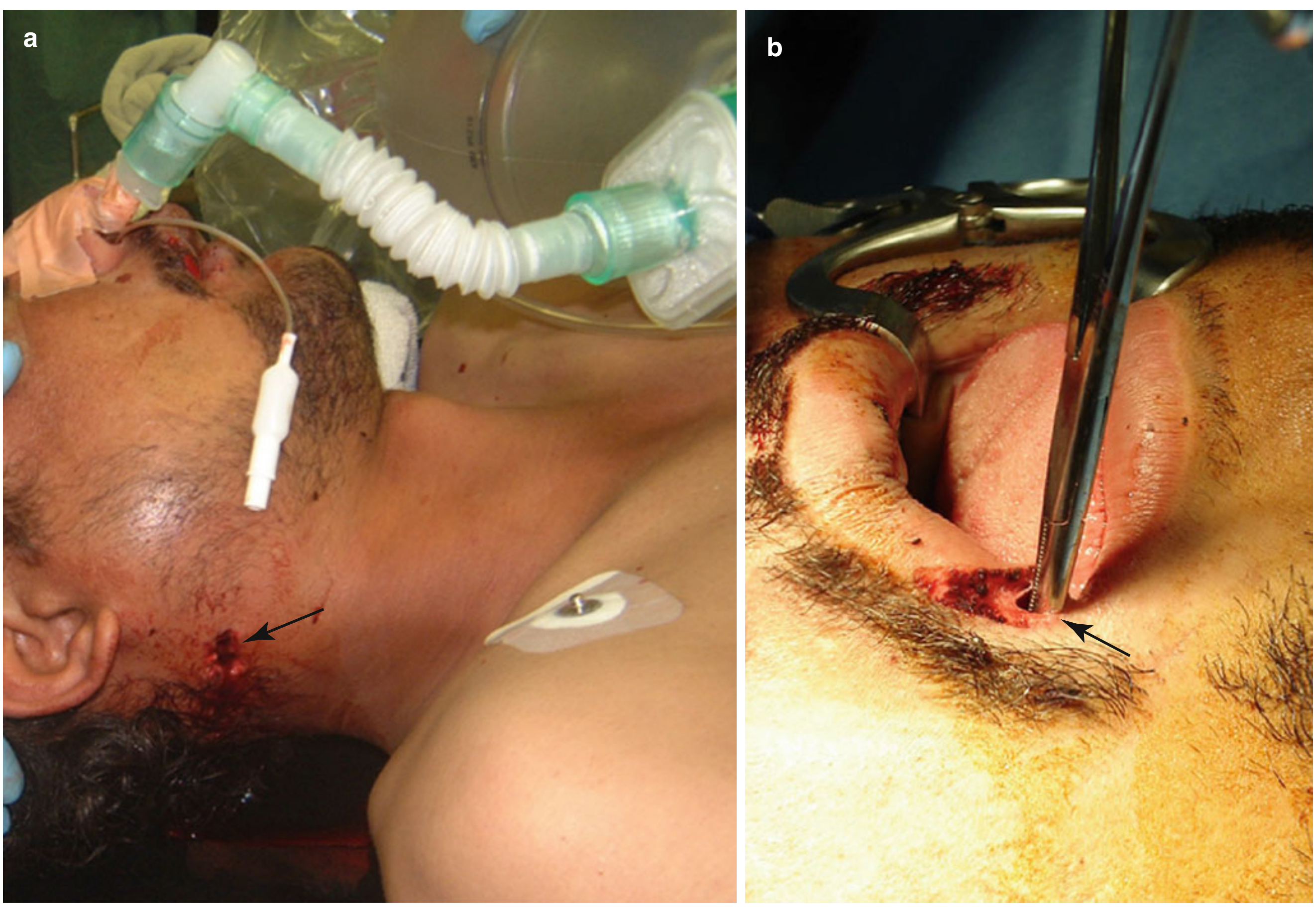

Fig. 15.14 High-velocity gunshot injury. Note the small entry (lip) and exit in the neck

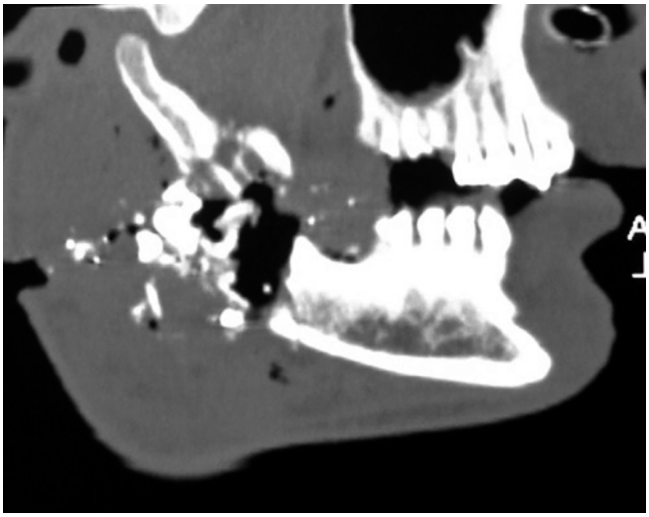

Fig. 15.15 CT scan showing extent of internal bony disruption

Fig. 15.16 Transosseous bicortical pins are inserted into the major fragments of the mandible. Aim for at least two pins in each major fragment and one or more in each sizable intermediate fragment

Fig. 15.17 A piece of plastic tube such as an ET tube or chest drain is cut to length and holes cut to accommodate the ends of the pins. The tube is then pushed over the pins and the tube filled with acrylic resin inserted with a large-bore syringe. The tube may be secured with wire or some other locking device if required

Table 15.3 Reconstructive principles in ballistic injuries

It is imperative that the tissue bed is viable and free of contamination or infection
Experimental evidence suggests that blast injury can affect the intima of vessels. This may propagate some distance from the wound, adversely compromising the local vasculature. This effect is thought to resolve over approximately 1 week. If doubt exists, angiography or some other vessel imaging is recommended to assess the presence and patency of vessels
Patients subject to blast injury are often extremely sick and this may impact on the complexity and length of surgery they can withstand in the early stages
There may be coexisting injuries to anatomical sites normally used to harvest flaps (e.g., limbs, hip). This may preclude the use of a preferred flap
There is still some controversy on the timing of definitive reconstruction. There is little doubt that delayed reconstruction leads to increased wound contracture, but immediate reconstruction must be tempered by the issues discussed above if a successful outcome is to be achieved

armamentarium of many reconstructive surgeons. Each of these flaps has particular qualities. Selection of the flap is therefore tailored to the particular defect.

Prior to complex reconstruction there are a number of issues particular to ballistic injuries that are worthy of note (see Table 15.3).

Ideally autogenous reconstruction should be the surgical aim. However, prostheses can prove to be useful temporary or permanent options for reconstruction. This is especially the case in areas such as the nose or ear where aesthetically good reconstruction is technically difficult. Titanium implants have revolutionised the retention of these prostheses.

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Craniofacial Fractures and the Frontal Sinus

16

Simon Holmes and Michael Perry

Craniofacial fractures by their very nature involve the combined efforts of both facial surgeons and neurosurgeons. The dura forms a convenient anatomical barrier to neurosurgical involvement—evidence of trauma to the dura itself, or any of the structures deeper to it mandates a neurosurgical opinion. All other facial injuries out with the dura do not, although consultation may still be advisable in some cases. Investigation and management of associated intracranial injuries always takes priority over facial injuries (once the airway has been secured and ongoing facial haemorrhage has been arrested). Because craniofacial injuries usually occur following high-energy impacts, either localised (e.g. struck by an object) or generalised (e.g. deceleration injuries), multiple specialities are often required in the overall management. Early involvement and a team approach is therefore essential in order to quickly establish the nature of any obvious (or occult) injuries and plan definitive care in a timely manner.

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16.1 Applied Anatomy

16.1.1 The Skull

The skull consists of the calvarium (which contains the brain) and the facial skeleton. The calvarium consists principally of eight bones (Table 16.1). These behave as a single functional unit. Unlike some bones of the face, the suture lines are very strong and fractures do not necessarily propagate along them.

The skull is thickest over the vertex. It is thinnest in the temporal region and where it forms the roof of the orbits and nose. (See for yourself. Get a real skull and hold it up to daylight. This graphically demonstrates how fragile some areas are). Skull thickness and the volume of the paranasal sinuses can vary significantly from person to person. Internally the skull is divided into the anterior, middle and posterior cranial fossae (Table 16.2).

Table 16.1 Bones of the skull

Frontal
Sphenoid
Temporal (2)
Parietal (2)
Occipital bones
A small part of the ethmoid bone completing the skull base anteriorly

Fig. 16.1 This case example demonstrates the need to consider the skull as a whole. The patient was found unconscious, lying next to a baseball bat. The fractures clearly transgress the anatomical subunits. The fracture configuration extends into the midface. Note the high Le Fort I fracture on the right maxilla. The maxillary fracture has occurred in a region of thicker bone, indicating a higher level of energy transfer

Fig. 16.2 On the left side the vault, fracture extends into the left skull base, with a Le Fort II maxillary injury extending into the nasomaxillary region. The whole of the upper third of the skull can be mobilised across this coronal fracture. The volume of energy transfer can thus be described as "spectacular." In view of the likely energy transfer to the brain, this injury, not surprisingly, was incompatible with life

Table 16.2 The cranial fossae

Anterior cranial fossa (ACF)
This forms the roof of the nose and orbits. The ACF is commonly fractured with injuries to the upper face (Le fort II, III and nasoethmoid fractures). It contains the anterior part of the frontal lobe and is perforated by the olfactory nerves
Middle cranial fossa (MCF)
This is the largest fossa and contains the temporal lobes. Above these lay the remainder of the frontal lobes, and the parietal and occipital lobes. It is separated from the posterior fossa by the tentorium cerebelli. The carotid arteries enter the skull though the MCF and cranial nerves II to VI exit the skull there. Fractures of the MCF require a lot of energy. Consider also carotid injuries
Posterior cranial fossa (PCF)
This lies below the tentorium cerebelli and contains the midbrain, pons, medulla and cerebellum. The major venous outflow of the brain occurs here, as the sigmoid sinus continues as the internal jugular vein. Cranial nerves VII to XII exit here. The medulla continues with the spinal cord through the foramen magnum. Fractures at this site may result in brain stem injuries and an unstable cervical spine

16.1.2 The Frontal Sinuses

The frontal sinuses make up one of the four groups of paranasal sinuses formed by extension of the ethmoidal air cells. They are absent at birth, but become reasonably well developed by the age of 7, reaching their full size after puberty. In up to 4 % of the population they can be absent. The two sinuses form a cavity within the frontal bone, consisting of anterior and posterior walls or "tables." These are highly variable in size and shape and are rarely symmetrical. A midline septum separates the two but this is also highly variable and usually deviates to one side. The average sinus is approximately 6–8 mL in volume.

Each sinus is lined with ciliated mucus-secreting epithelium. Mucus drains into the middle meatus of the nose via the frontonasal ducts (also called frontal sinus drainage pathways [FSDP]). The openings of the ducts are usually seen in the posteromedial floor of the sinus. From there they then pass through the ethmoid labyrinth taking a variable pathway. This is an important point to remember when managing apparently isolated nasoethmoid fractures. One of the main concerns in the management of frontal sinus and nasoethmoid fractures is the patency of the duct. In some fractures there is a high risk of obstruction which can result in stasis of sinus contents. Continued mucus production results in mucocele formation which in itself weakens the surrounding bone.

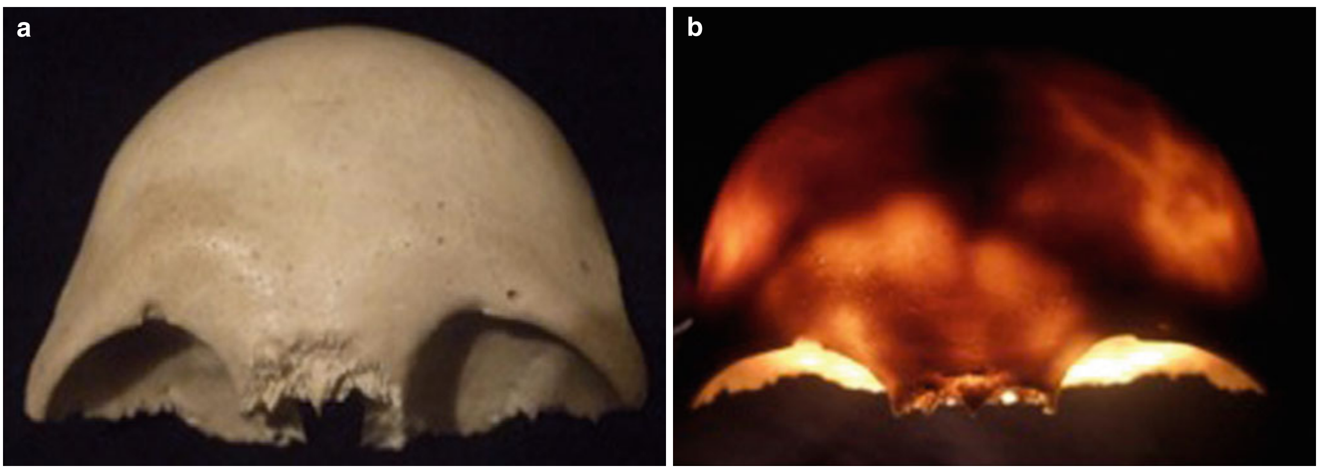

Fig. 16.3 Transilluminated frontal sinus (**a**, **b**)

Fig. 16.4 The frontal sinus drains into the nose via the ethmoid sinuses. Isolated NOE injuries can still impede free drainage. It is around the drainage of the frontal sinus that classification, management, and complications are explained

Subsequent infection can lead to mucopyocele, erosion of the posterior table, meningitis or brain abscess.

Frontal sinus fractures can be classified into fractures of the anterior table, posterior table, or fractures of both. The “floor” of the sinus is sometimes included with the posterior wall. Most anterior fractures are of cosmetic importance only and repair can therefore be elective. However, displaced anterior table fractures that occur in the glabellar region carry a risk of duct obstruction. Posterior table fractures usually occur with anterior table fractures. Those that are displaced more than the width of the posterior table are reported to be at an increased risk for dural injury and cerebrospinal fluid (CSF) leaks. Whether they require surgical intervention or can be managed expectantly is a controversial topic. Intracranial injury is common with posterior table fractures.

16.1.3 The Meninges

Between the skull and brain are three membranous layers, the meninges. The outer membrane, the dura mater, is a tough fibrous membrane which lines the inner surface of the bone. This becomes more firmly attached with increasing age. The dura also forms several internal partitions: the falx cerebrum (which separates the two cerebral hemispheres), the tentorium cerebelli (which separates the middle and posterior cranial fossae) and the falx cerebelli (which separates the two cerebellar hemispheres). The “extradural space”, between the dura and skull is a potential space only. Normally it does not exist.

Venous drainage of the brain occurs through several large venous sinuses. These lie within the dura (several within the falxes) and drain into the internal jugular vein through the jugular foramen. The cavernous sinuses lay alongside the sella tursica (pituitary fossa). These receive venous drainage from the face and are therefore a potential route for intracranial spread of extracranial infection. The importance of the venous sinuses is that they can easily tear during fracture repair and bleed profusely. Particular care is required with overlaying fractures (especially depressed fractures).

The arachnoid mater lies deep to the dura. This is a flimsy membrane that comprises the parietal layer of the “lepto” (or thin) meninges. The “subdural space” lays between the dura and arachnoid and is usually empty. The “subarachnoid space” lays deep to the arachnoid and contains the CSF. This supports and cushions the brain. At various places, mostly around the base of the brain, the subarachnoid space is very large, forming the “basal cisterns.”

The pia mater is the visceral layer of the leptomeninges. This very delicate layer is firmly attached to the brain.

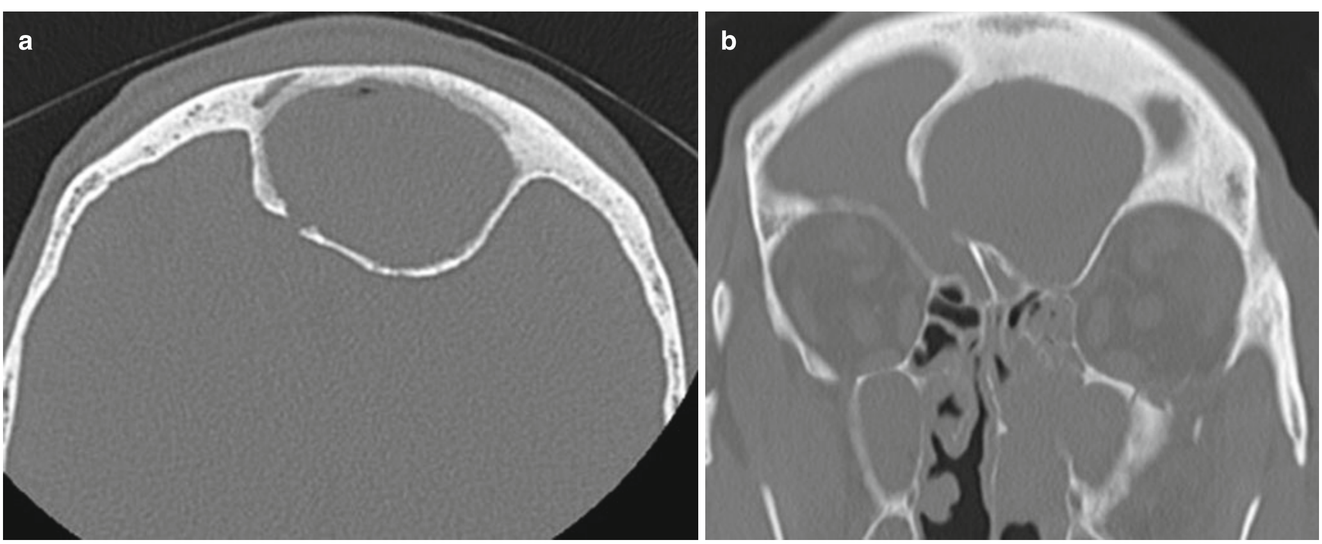

Fig. 16.5 A large mucocele of the frontal sinus (**a**, **b**). This has probably been present for years and was discovered purely by chance (following a second injury). The patient had suffered upper facial injuries 4 years prior to this presentation

16.1.4 The Brain

Table 16.3 Basic brain anatomy

Cerebral hemispheres
These are connected by the corpus callosum. Descending white matter tracts from the cortex converge to form the internal capsule en route to the brainstem. Injuries here can result in a major deficit. Ascending sensory fibers (except olfaction) relay in the thalamus, which is lateral to the internal capsule. The other basal ganglia are concerned with motor function, and have complex interconnections. The hypothalamus is concerned with autonomic and endocrine function
Cerebellum
This is concerned with balance and coordination. It consists of two hemispheres and the midline vermis. It is divided into three lobes (anterior, posterior and flocculonodular lobe). Damage to the vermis causes ataxia and unsteadiness on sitting (truncal ataxia). Damage to the cerebellar hemispheres results in loss of coordination on the same side of the lesion
Brainstem
The midbrain, pons and medulla contain nuclei for the third to twelfth cranial nerves, together with descending and ascending fibre tracts. The brainstem reticular formation contains centers for the vital functions (wakefulness, pulse and blood pressure control, breathing)

Table 16.4 Cerebral hemispheres

Each hemisphere comprises four lobes (frontal, temporal, parietal and occipital) separated by three fissures (central, parieto-occipital and Sylvian). The surface is highly convoluted into gyri (the folds) and sulci (the clefts), which increase the area of the cortex. This is where the "higher" functions occur. Cortical functions are crossed, that is, one hemisphere deals with the function of the other side of the body
The left hemisphere is dominant for speech in 99 % of right-handed individuals and in 50 % of left-handed individuals. A number of functional anatomical sites are now well known. Correlation of these with signs of injury on CT scans help predict prognosis in recovery
Primary motor area is in the precentral gyrus of frontal lobe
Primary sensory area is in the postcentral gyrus of parietal lobe
Speech motor area (Broca's area) is in the infero-lateral frontal lobe
Speech interpretation area (Wernicke's area) is in the inferior parietal lobe and upper temporal lobe
Visual cortex. Tip of occipital lobe, especially medial surface
Auditory cortex. Superior temporal gyrus
Higher intellectual functions. Tip of frontal lobe
Emotions. Frontal lobe, temporal lobe, cingulated gyrus and limbic system
Olfactory function. Infero-medial temporal lobe
Other parietal lobe functions include numeration, calculation, body image and awareness of external environment

16.1.4.1 Cerebral Blood Supply

The internal carotid and vertebral arteries supply the brain with blood. The internal carotid artery enters the skull via the carotid foramen in the middle cranial fossa (MCF) and divides into the anterior and middle cerebral arteries. Due to the high energy required, fractures in the MCF should raise concerns about vascular injury. The two vertebral arteries unite to form the basilar artery, which then divides into the two posterior cerebral arteries. These supply the cerebrum, cerebellum, and brainstem. Autoregulation maintains a steady flow of blood, so that there is little variation in pressure within the delicate tissues of the brain. However, this mechanism is usually impaired following a head injury. The cerebral perfusion pressure (CPP) is the force driving blood through the brain and is normally over 70 mmHg. It is dependent on the blood pressure (BP) and intracranial pressure (ICP). CPP = BP − ICP.

16.1.5 Ventricular System

The two lateral ventricles are C-shaped cavities within the cerebral hemispheres. These contain the choroid plexus, which produces around 450 mL of CSF daily. Only 20 mL of CSF is in the ventricles; the rest is circulated throughout the subarachnoid space. Leaving the ventricles, CSF passes through the foramen of Monro into the slit-like third ventricle (a useful landmark on CT scans). This connects with the cerebral aqueduct and then with the fourth ventricle before exiting the ventricle via the foramina of Magendie and Luschka. CSF is replaced approximately 3 times every day. Following circulation it is passively resorbed through the arachnoid villi over the cortical surface. Blood in the CSF (from either traumatic or spontaneous subarachnoid haemorrhage) can block this process, resulting in raised ICP.

16.2 Understanding Head Injuries

The aim of head injury management is to prevent secondary brain injury from occurring as a result of various mechanisms. This involves regular assessment of the patient and rapid intervention if any deterioration occurs. Maintaining the optimal physiological environment maximises the brain's recovery from the primary injury.

"Primary" brain injury (Table 16.5) occurs at the time of impact. As such there is nothing we can do about this other than by primary prevention. "Secondary" brain injury occurs after the initial event and is due to a variety of mechanisms (Table 16.6). One way or another, these all result in either hypoxia or inadequate cerebral perfusion. Hypoglycaemia is another important (and preventable) cause of secondary injury.

Table 16.5 Primary brain injury

Cortical lacerations (burst lobe)
These are usually associated with contusions and acute subdural/cerebral haematomas. There is often marked swelling. Craniotomy is necessary for haematoma evacuation and debridement. The prognosis is usually poor
Cerebral contusions
Blood is diffusely interspersed between the neurones and glia. Contusions often occur at the poles of the brain following a contra-coup injury. They are usually treated conservatively, but may require evacuation if extensive and the ICP is critically raised
Diffuse axonal injury
This consists of widespread disruption of neural sheaths. It is particularly associated with impacts and rotational injuries. CT may be normal, but often shows brain swelling with petechial haemorrhages. The prognosis is usually poor
Concussion
This is a transient impairment of consciousness following a minor or moderate head injury. This is a mild diffuse axonal injury and recovery is usually complete

Table 16.6 Secondary brain injury: common treatable causes

Hypoxia, hypotension, hypovolaemia and hypoglycaemia
Whatever the cause, the final common pathway remains the same: the brain is deprived of oxygen. Following trauma, the brain is particularly sensitive to hypoxia. Hypogycaemia is another preventable cause of secondary brain injury
Extradural Haematomas (EDH)
These are usually associated with a skull fracture, the commonest site being temporal, which results in a tear of the middle meningeal artery. Patients classically present with delayed deterioration. Since the primary brain injury is usually mild, this accounts for the "lucid interval." EDH appear as high-density lens-shaped lesions on CT scans. Very small extradurals with minimal symptoms can often be left, although most need a craniotomy for evacuation. The prognosis is very good if treated early
Acute Subdural Haematomas (SDH)
These occur following a tear of a bridging vein between the brain and skull, or a laceration of the brain surface (burst lobe). There may be no skull fracture. SDH extend over the surface of the cortex and are crescent-shaped on CT scans. Thin subdurals can be treated conservatively, but large ones need drainage. Chronic subdural haematoma is thought to arise from repeated minor bleeding, following a minor head injury. This is common in the elderly and in alcoholics
Cerebral Contusions and Haematomas (see also primary brain injury, Table 16.5)
In contrast to contusions, cerebral haematomas form a clot within the brain. However, cerebral contusions can enlarge and coalesce into a haematoma
Together with any swelling, all three of these haematomas can critically raise the ICP. This reduces the perfusion of the brain—again resulting in hypoxia

16.2.1 Pathophysiology

> The brain is the most sensitive organ in the body to hypoxia and ischaemia. Therefore, it is essential to maintain an adequate supply of well-oxygenated blood to it, especially when it has been injured.

Whatever the cause, the final common pathway for secondary brain injury remains the same—the brain is deprived of oxygen (or sometimes glucose). In a sense, the whole aim of the rapid primary survey in Advanced Trauma Life Support (ATLS™) is to maintain the delivery of oxygenated blood (preferably the patient's own blood) to the brain. Crudely speaking this process may fail due to a number of mechanisms (Table 16.7).

> In the very early stages of reduced cerebral perfusion, there is loss of higher functions, notably how alert the patient is. This is why the Glasgow Coma Scale (GCS) is so important in assessment. This can be confused with a number of other causes, notably alcohol, drugs, hypoglycaemia, hypoxia and fatigue.

Any developing intracranial mass will at first be compensated for by displacement of venous blood and CSF. This is sometimes known as the Monro-Kellie doctrine. At this stage the ICP will not rise. However, when the compensatory mechanism, already at reduced capacity due to damaged brain reaches its limit. The ICP will then rapidly rise and the CPP quickly fall. Cushing's reflex then comes into play, increasing the systemic blood pressure to maintain cerebral blood flow. The pulse rate consequently falls due to a reflex vagal response. As a result, progressive cerebral ischaemia occurs, which untreated leads to cerebral infarction and brain death. A vicious circle becomes established with increasing hypoxia, hypotension and cell breakdown products, which further worsens the cerebral oedema. If this continues, untreated brain herniation will eventually occur ("coning").

Table 16.7 Reaching the "final common pathway" in secondary brain injury

Hypoxia
Obstructed airway (FB, facial injuries)
Inadequate ventilation (reduced respiratory rate, pneumothorax, haemothorax, etc.)
Not giving oxygen
Hypovolaemia
Internal/external blood loss (including facial injuries)
Hypotension
Cardiac causes, drugs, spinal injuries
Raised intracranial pressure (ICP) and reduced brain perfusion
EDH, SDH, Cerebral contusions/haematoma, cerebral oedema
Depressed fractures

16.3 Assessment of Head Injuries

> The importance of the GCS, like many investigations, is that it is a "snapshot" of the patient's condition at the time it was taken. To be of use it must be repeated on a regular basis to detect change. Only this way will it be possible to quickly pick up any improvements or deterioration in the patient's neurological status.

When assessing head injuries, there are a number of key features in the history which should be determined if possible. The mechanism of injury provides important clues to the possible severity and certain injury patterns. Sudden deceleration, for instance, will transfer more energy to the brain than a stationary person struck by a moving object. Penetrating injuries through the orbit can be easily overlooked. The time of the injury should be established, since any change in the patient's neurological condition gives an indication of how rapidly secondary brain injury is evolving. The conscious state immediately after the injury reflects the presence of primary brain injury and the potential for recovery. Delayed loss of consciousness implies complications are developing. Post-traumatic amnesia is also reported to reflect prognosis.

Examination always starts with an assessment of the resuscitation status; a GCS does not accurately reflect brain injury if the patient is unconscious from some other reason. Blood pressure, oxygen saturation and blood glucose should all be checked. Ideally the blood alcohol should be known if appropriate, although any reduction of consciousness should not be attributed to alcohol, even if it is high. The Glasgow coma scale is a well-known measuring tool and should be repeated regularly. Unequal but reactive pupils (anisocoria) occur in about 20 % of normal individuals. A dilated unreactive pupil secondary to intracranial "mass effect" is usually on the same side as the mass lesion. A focal neurological deficit may also be present. However, a hemiparesis can be caused by either a mass lesion pressing on the opposite motor cortex, or a mass on the same side compressing the opposite cerebral peduncle against the edge of the tentorium. Therefore. a hemiparesis by itself does not help in determining the side of a mass lesion. This is called a "false localising sign."

Localised signs of injury should also be looked for (CSF rhinorrhoea or otorrhoea, Battle's sign, panda eyes, scalp lacerations).

In the unconscious, anaesthetised or poorly responsive patient, examination becomes more difficult (Table 16.8). Although identification and treatment of injuries are the main concern, associated medical conditions and medication (notably anticoagulants and steroids) should never be forgotten.

Table 16.8 Neurological examination of the unconscious patient

Resuscitation status
Glasgow coma scale
Pupil responses
Eye movements and fundoscopy
Signs of injury
Brainstem reflexes
Limb tone
Limb movements (spontaneous, localising, flexion, extension, or absent)
Limb reflexes and plantar response
Other useful clues include:
Abnormal skin colour (cyanosis, jaundice, rubor in carbon monoxide poisoning)
Needle-stick marks (drug overdose)
Smell of breath (alcohol, ketosis, uraemia, cyanide)

16.3.1 The Glasgow Coma Scale (GCS)

> When discussing the GCS, always make it clear which score you are using. The original GCS had a maximum score of 14 not 15. Some units may still use this score, so be clear, especially if you are transferring or receiving a patient from elsewhere.

The GCS was originally devised as a means of consistently recording and describing the level of consciousness in a patient, in a reproducible manner. It also allowed for monitoring of any change. This involves assessing three responses:

- Eye opening
- Motor
- Verbal

Table 16.9 Glasgow coma scale in adults

Eye opening response	Motor response	Verbal response	Score
	Obeys commands		6
	Localizes pain	Orientated	5
Spontaneous	Normal flexion	Confused	4
To speech	Abnormal flexion	Words only	3
To pain	Extension	Sounds only	2
Nil	Nil	Nil	1

Patients should be described according to each of the three responses. This gives a clearer indication of their status (e.g., "eyes are opening to speech, disorientated and localising to pain," not just "the GCS 12"). Head injuries are generally classified as minor, moderate and severe based upon the overall GCS score. Progression down the scale indicates a worsening condition and a worsening prognosis. Patients with no eye opening, no motor and no verbal response (GCS 3) are unlikely to survive. A dead patient has a GCS of 3 not 0!

Minor	GCS 13–15
Moderate	GCS 9–12 (or 7–8 with eye opening)
Severe	GCS ≤8 ϑ

Table 16.10 Glasgow coma scale in young children

Eye opening response	Motor response	Verbal response	Score
	Spontaneous movement		6
	Localizes pain	Usual vocalisation	5
Spontaneous	Normal flexion	Reduced vocalisation	4
To speech	Abnormal flexion	Cries only	3
To pain	Extension	Moans only	2
Nil	Nil	Nil	1

16.3.2 Investigations

Computed tomography (CT) scanning is now the investigation of choice in the assessment of significant craniofacial trauma. Plain films ("skull x-rays") are now virtually obsolete in most modern units. CT technology has rapidly evolved, not only significantly reducing radiation dosages,

Table 16.11 Indications for CT scan in head injured/unconscious patient

GCS <13 on initial assessment in the emergency department
Neurological deterioration in resuscitated patient
GCS <15 at 2 h after the injury
Suspected open or depressed skull fracture
Any sign of basal skull fracture (haemotympanum, "panda" eyes, CSF leaking from the ear or nose, Battle's sign)
Post-traumatic seizure
Focal neurological deficit
More than one episode of vomiting
Amnesia for events more than 30 min before impact
Diagnosis uncertain
Tense fontanelle in a child

but also reducing the acquisition times, such that imaging of the face is now also possible during the assessment of serious head or torso injuries. This avoids additional transfers later, facilitating comprehensive treatment planning. On this basis, any patient requiring a brain CT (Table 16.11), who has suspected midface injuries, should also undergo imaging of (at least) the orbits, although ideally the whole face should be scanned. Skull base, orbital apex and ocular injuries needs rapid identification. CT is particularly useful in assessment of the skull base, nasoethmoid region, orbits, sinuses, zygomatic arch, (facial projection) and condyles. This requires both axial and coronal views.

16.3.3 CSF Leaks

> If a CSF leak is present or suspected, the patient should be advised not to blow their nose for 3 weeks. Sudden increases in intranasal pressure can sometimes force air intracranially through the dural tear, which then cannot escape. Think of this as the neurosurgical equivalent of a tension pneumothorax. There is also the risk of introducing infection.

Facial fractures which extend into the base of the skull (e.g., Le Fort II, Le Fort III, nasoethmoidal and occasionally fractures involving the mandibular condyle) can tear the dural lining and allow CSF to leak from the nose (rhinor-

rhoea) or from the ear (otorrhoea). Clear CSF mixes with blood and presents as a blood-stained, watery discharge. As it trickles down the face the blood clots peripherally, while the nonclotted blood in the centre is washed away with the CSF. This forms two parallel lines referred to as “tramlining.”

One test for CSF is the “ring test”: allow a few drops to fall on tissue paper; the blood clots centrally, while clear CSF diffuses outwards. Other tests include examining fluid for eosinophils and sugar. This is helpful in distinguishing between CSF and mucous. More sensitive indicators include beta-2 transferrin or tau protein, although practically it is easier to simply assume that a leak is present.

16.3.4 Vascular Complications

These complicated injuries are seen in high-energy impacts, where fractures extend from the orbit through the anterior skull base to the intracranial compartment. Immediately deep to the orbital apex is the cavernous sinus, and carotico-cavernous fistulae may occur.

Fig. 16.6 Cerebrospinal fluid leakage. Note the tramlining. Also note the CSF dripping from an upper eyelid laceration. These signs (plus the well-defined black eye) indicate that the patient must have (at the least), fractures involving the orbital roof, associated with a dural tear (**a**, **b**)

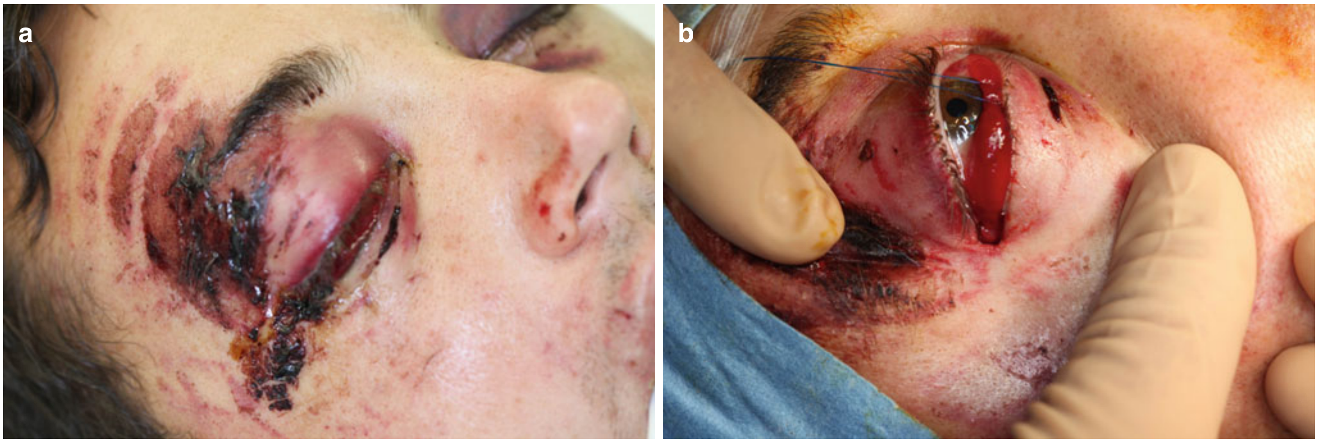

Fig. 16.7 Caroticocavernous fistula (**a**, **b**). The physical signs relate to the intense venous engorgement, with extensive conjunctival chemosis and pulsatile proptosis. Frequently these injuries are associated with loss of vision due to optic nerve damage

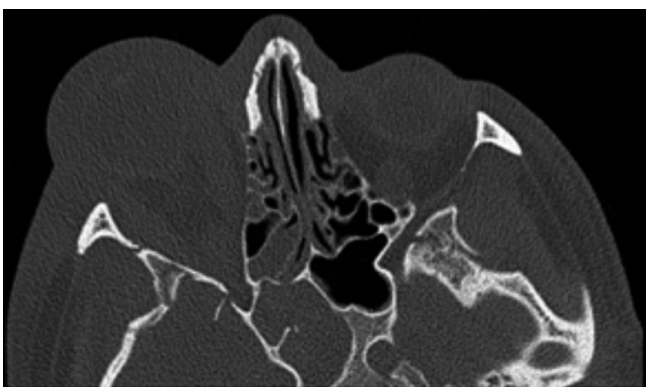

Fig. 16.8 The axial CT scans in this case demonstrate fractures at both orbital apices. The intense proptosis of the right eye can be seen. This was pulsatile

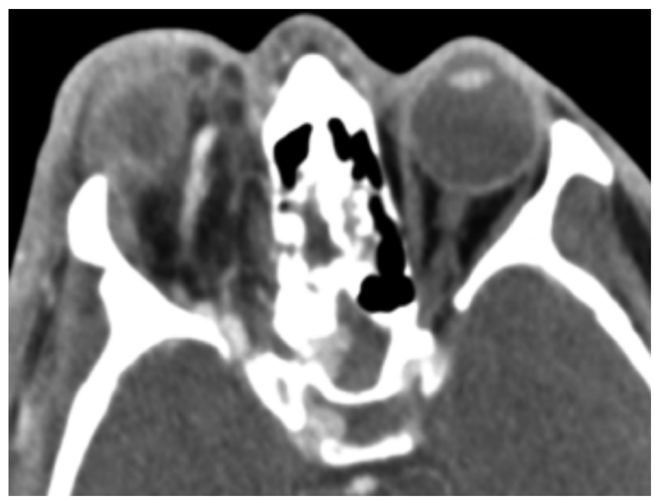

Fig. 16.9 A contrast scan demonstrates arterial flow in the orbital vessels, which is diagnostic for this condition

16.4 Principles of Management in Craniofacial Trauma

The management of craniofacial trauma embraces several key principles:

- Neurosurgical (as previously discussed)
- Aesthetic
- Structural
- Functional

16.4.1 Aesthetic

The forehead and vault (as with the rest of the craniofacial skeleton) act as a three-dimensional scaffold. Any defect or deformity in this region will impact aesthetically. Initially, mild defects will be concealed by soft tissue swelling, or may be considered unimportant by non-specialists. However, once the swelling has fully resolved, bone defects or malpositions may become more noticeable.

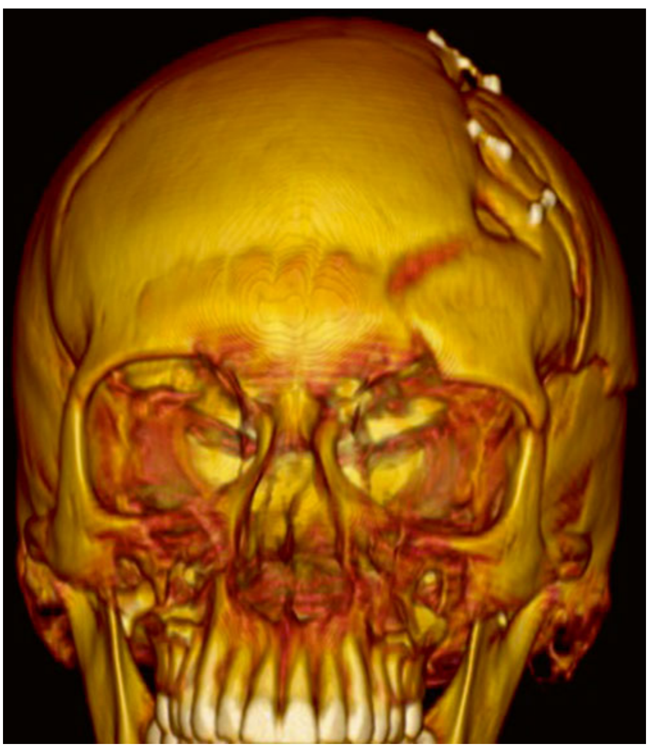

Fig. 16.10 This image shows a patient referred following neurosurgical decompression. Note the malposition of the left supraorbital ridge which has been inaccurately repositioned. The patient had significant orbital dystopia with marked left hypoglobus

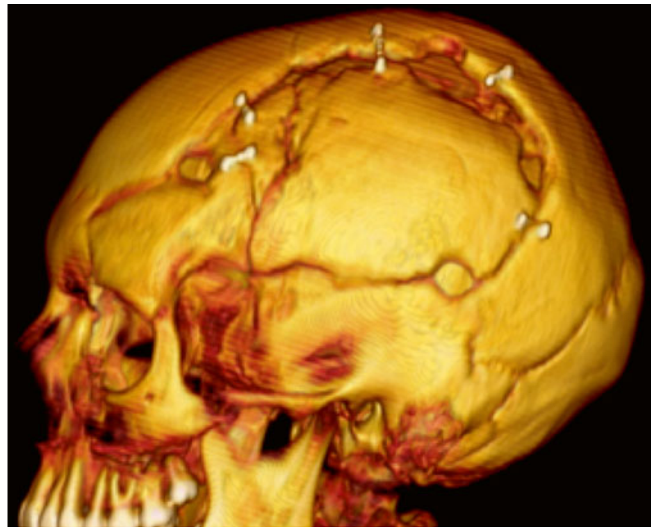

Fig. 16.11 The lateral view of the same patient demonstrates the malposition of the craniotomy bone flap, with inadequate fixation. There is also a discrepancy of the posterosuperior border. This resulted in a pulsatile cutaneous hollow ridge in the scalp

16.4.2 Structural

The portion of bone running horizontally across the forehead from one frontozygomatic suture to the other is sometimes referred to as the "frontal bandeau." This region must be repaired accurately in all three dimensions in order for the middle and lower face to have solid and anatomically precise articulations.

16.4.3 Functional

This refers to the frontal sinus and maintaining its function and drainage. Failure to do so can have serious consequences (discussed later) .

16.4.4 Planning Repair

Planning the repair of these complex injuries is usually a team effort, requiring the skills of a number of specialties (notably neurosurgery, ophthalmology and anaesthetics), in addition to ourselves. Surgery needs to take into account the aims of overall management (Table 16.12), and may be modified by the general physiological status of the patient. This is discussed elsewhere.

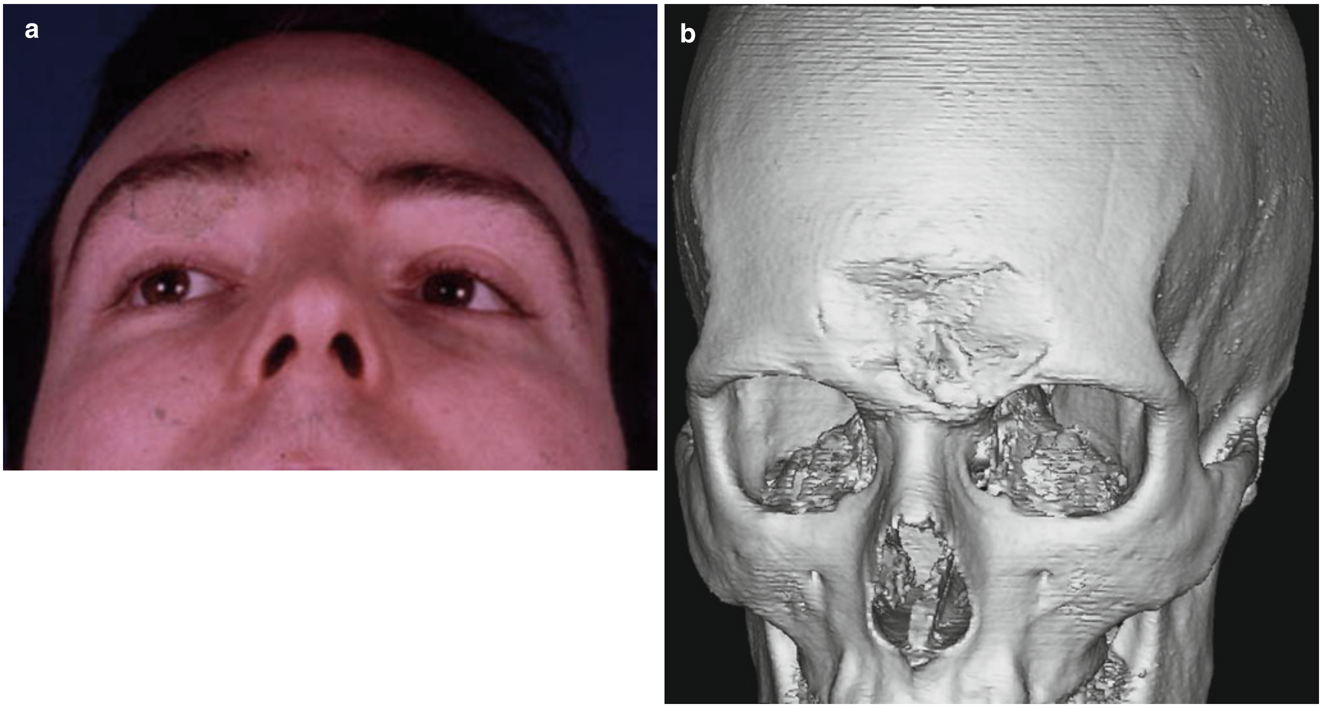

Fig. 16.12 Anterior sinus wall fractures are extremely common, and often undertreated. In this case the bone defect resulted in hollowing above the brow (**a**, **b**). This characteristically concave defect traps light and is usually very noticeable

Fig. 16.13 Errors built into the repair of the frontal bandeau are conveyed lower down the face, as sequential reconstruction progresses. The region of the bandeau above the nose provides structural support for plates reconstructing the NOE region

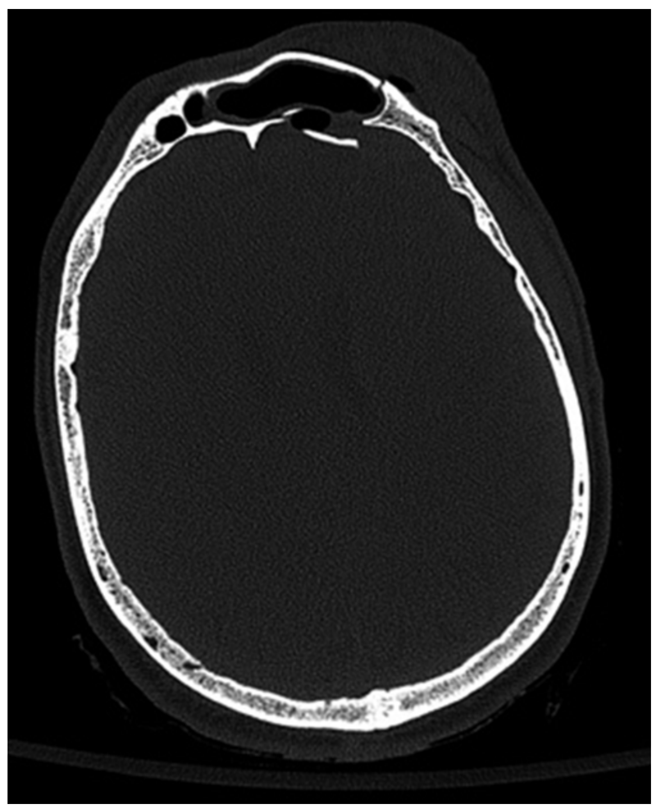

Fig. 16.14 Disruption of the anterior and posterior walls of the frontal sinus carry serious consequences both aesthetically and with the potential spread of infection from the nose into the intracranial compartment

Table 16.12 Management Considerations in Craniofacial Injuries

Initial management
Life-threatening injuries (ATLS™)
Cervical spine injuries and protection
Is immediate neurosurgical intervention required? (EDH, SDH, Depressed fractures)
Occult injuries (especially if unconscious/intubated)
Surgical repair
Consider the following
Management of brain injury (evacuation of clots, ICP monitor, etc.)
Elevation of any depressed skull fractures (? leave in situ, if over sagittal sinus)
Repair of dural tears
Management of the frontal sinus (accept, cranialise, obliterate etc.)
Repair of orbital roof(s)
Management of any orbital apex fractures
Repair of associated globe injuries
Repair of any NOE fractures

In most complex cases, access requires a coronal flap. This is often supplemented with a few local incisions (lower eyelid, intraoral).

> When sequencing multiple incisions, lower eyelid access and cantholysis must be performed first and closed last. If not, it will be difficult to predictably reattach the lateral canthus.

16.4.5 Planning a Coronal Incision

Although the coronal approach is a well-established "standard" approach to the upper craniofacial skeleton, variations in its design exist. Modifications may be required based on a number of factors specific to each patient. These include:

1. The extent of injury
2. The hair line: scars should be hidden behind this.
3. Preauricular extension: this may need to be increased or decreased depending on the lateralisation of the injury.
4. Nasoethmoid exposure: this affects the extent of caudal midline dissection.
5. Confounding lacerations: may help or hinder.
6. Confounding neurosurgical fractures

Fig. 16.15 Accurate planning of surgical access is important. The upper craniofacial skeleton can be divided into a number of zones. Fractures of the forehead and adjacent articulation of the zygoma are in the *yellow zone*. The *blue area* requires detachment and reattachment of the temporalis muscle. The *red area* allows access to the zygoma. The *green* and *purple areas* require access which facilitates extension into the NOE region

7. The extent of orbital injury
8. Pericranial flap design

Raising a coronal flap can be considered in a stepwise manner, modified according to the regions that need exposure. Each region has its own challenges and techniques.

16.4.5.1 Access to the Midline Forehead

Planning involves several stages:

1. Positioning
2. Hair management
3. Insufflation
4. Skin incision
5. Developing the incision
6. Raising the flap
7. Management of neurovascular structures

16.4.5.2 Positioning

The patient is placed supine on the table, which is tilted head-up in a reverse Trendelenberg position (this may be contraindicated in some neurosurgical injuries if there is a high risk of air embolism via torn venous sinuses). Any coexisting cervical spine injury must be supported appropriately. Often a Mayfield clamp is placed. This maintains the neck in a neutral position and prevents turning of the head during the procedure. Otherwise a Rubens pillow or rigid neck collar may be used depending on the surgeon's preference.

16.4.5.3 Hair Management

This is very much down to personal preference. Some surgeons have very strong views which may vary according to surgeon, specialty, and patient. Although shaving the head can make surgery so much easier, some patients may not accept this for a less serious injury, such as a fractured zygoma.

16.4.5.4 Insufflation

This is a useful manoeuvre, but not all surgeons undertake this. Care is required if there are underlying skull fractures. Injection of a solution defines and hydrodissects the correct tissue plane, thereby simplifying surgery and reducing blood loss. The solution consists of:

- 40 mL of 0.25 % Marcain
- 15,000 units of Hyalase
- 100 mg of hydrocortisone
- 1 mL of 1 on 1,000 adrenaline
- ….in a 500 mL bag of normal saline. This is injected using a yellow spinal needle.

16.4.5.5 Skin Incision

This typically runs from ear to ear across the vertex of the scalp. Anatomically the vertex represents the watershed between the nerve supplies of the ophthalmic division of the trigeminal nerve and the spinal nerves of the cervical plexus.

Fig. 16.16 The coronal approach is best suited for access to the upper craniofacial skeleton. This includes the frontal bone, frontal sinus, NOE region, neurosurgical injury and access to zygoma (especially if there is telescoping of the zygomatic arch). The yellow area indicates what can be reached easily via a coronal flap - without extension preauricularly. If the zygoma is to be exposed preauricular extension must be included in the flap design

Since this is by definition the top point of the skull, it should be least visible to an observer. In male pattern baldness (either present, developing, or from a strong male family history), variations in design take the incision posteriorly. The vertex incision is laterally extended to the root of the ear. Preauricular extension is only required if there is a need for a laterally based pericranial flap, extensive exposure, or to deglove the zygomatic arch.

16.5 Placing a Mayfield Clamp

The Mayfield clamp is commonly used in most neurosurgical procedures. This facilitates greater access to the head and rigidly supports the cervical spine. However, the clamp can restrict access to the occlusion, palate and lower face. Turning the head to improve lateral access is also prevented.

> If a Mayfield clamp is used, there is a tendency for the scalp to be pulled back posteriorly, and skin closure may be difficult. If this occurs replace the clamp with a Rubens pillow when closing.

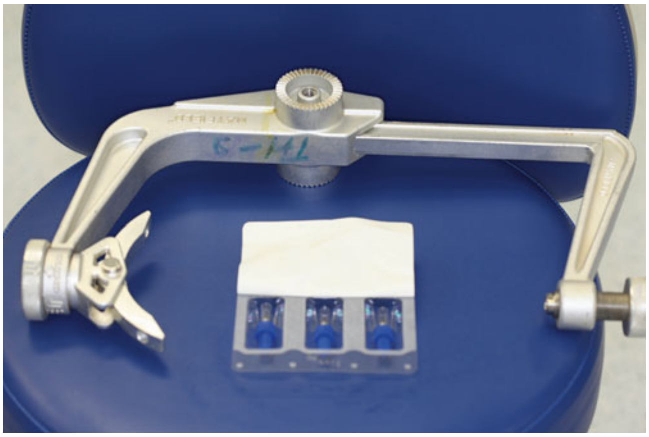

Fig. 16.17 The Mayfield Clamp. Components of the clamp include disposable pins

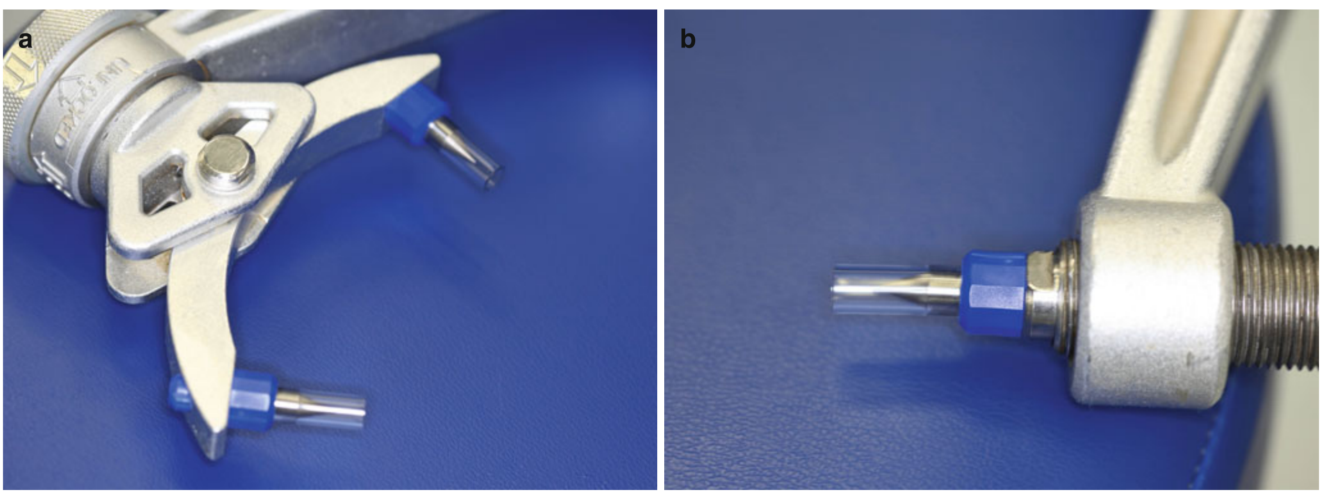

Fig. 16.18 The pins are located into the clamp (**a**). Note that the pins themselves are sheathed (**b**). The plastic sheath is removed when the surgeon is ready to place the device

Fig. 16.19 The clamp is placed over the skull fixation points. The site of pin fixation must take into account any planned incisions and the presence of skull fractures

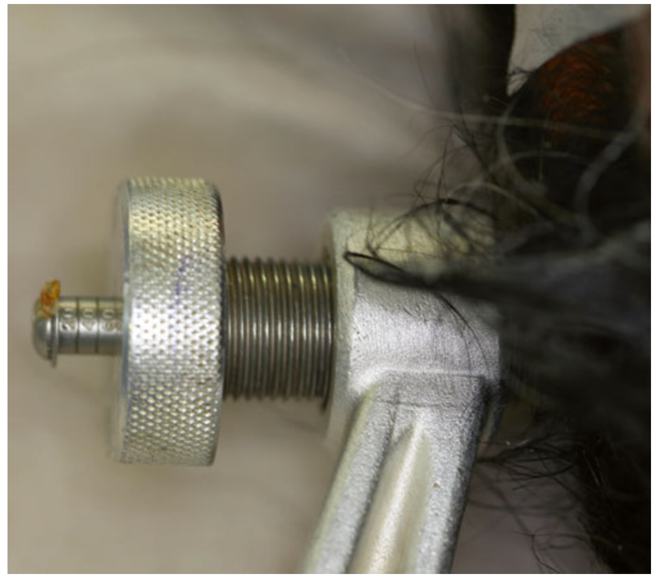

Fig. 16.20 The single pin side is then tightened. Note the Vernier scale on the thread. This ensures that there is little chance of iatrogenic skull fracture

Fig. 16.21 The two-pin dial is then locked. Note the position of the arrows on the collar and dial

Fig. 16.22 The head is supported and the head of the table is removed

Fig. 16.23 Once the head is positioned correctly, the posterior superior clamp is tightened and locked

Fig. 16.24 Finally the clamp is locked inferiorly. This ensures rigid stability of the neck and skull

16.6 Raising the Coronal Flap

This is also discussed in the chapter on coronal flaps.

Fig. 16.25 In this example, the scalp has been partially shaved. The patient had sustained comminuted scalp lacerations during a fall from scaffolding. Note the Mayfield clamp. The shave was required to ensure the correct incision design to include elements of the lacerations and avoid devitalising islands of skin

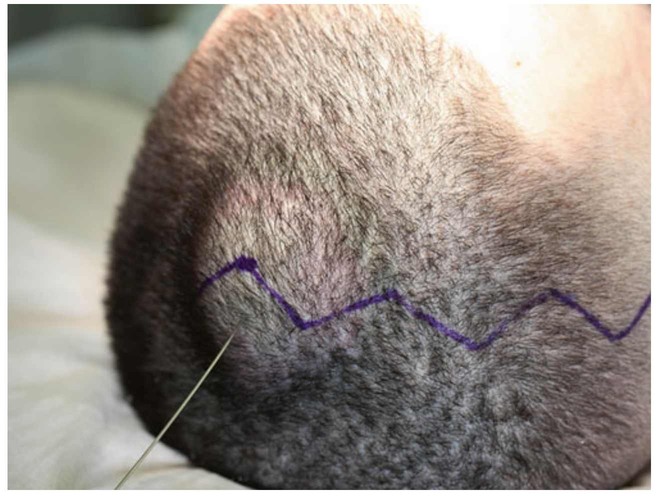

Fig. 16.26 In patients that have short hair and a healthy scalp, hair can largely be ignored. Here we see the early stages of insufflation

Fig. 16.27 If shaving is undesirable, the hair may be made manageable by careful preoperative washing and selective combing along natural partings

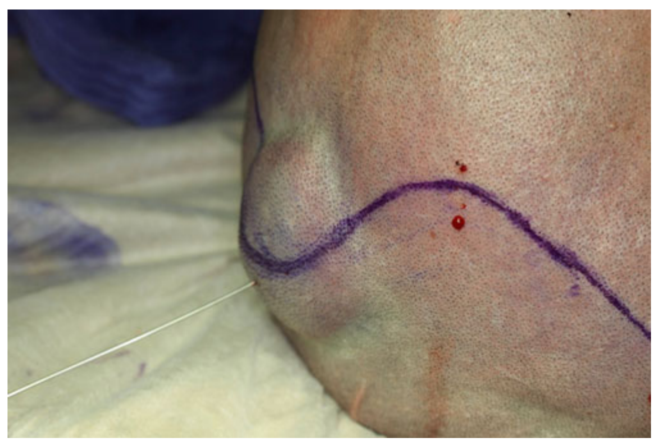

Fig. 16.28 To insufflate, the solution is injected in the subgaleal plane between the superior temporal lines. This is progressed along the cavities produced and along the incision line. This stage is best avoided if there are extensive skull fractures

Fig. 16.29 Once a significant volume is injected (usually around 100 mL), the fluid may be massaged gently toward the superior orbital margin. The time taken for the surgeons to scrub and drape is ample time for the soft tissue vasoconstriction to reach a therapeutic effect

Fig. 16.30 The skin incision can be carried out using either a scalpel or cutting diathermy. This is made slightly oblique, parallel to the hair follicles, starting in the midline and extending approximately 5 cm. The aim is to enter the fluid-filled cavity, but not to incise the pericranium. Normally there is a flush of liquid at this point

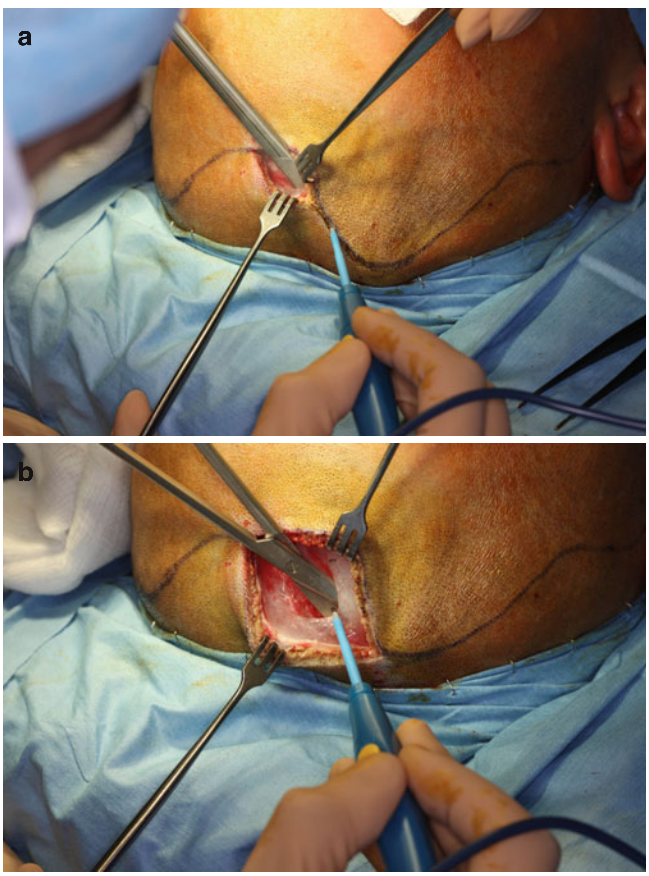

Fig. 16.31 McIndoe (or some other blunt tipped) scissors are then used to propagate the plane (**a**), and the skin is incised further (**b**)

Fig. 16.32 Blunt dissection with a finger may also be a highly efficient way of propagating the dissection (ensure there are no splinters of bone, glass, etc.!)

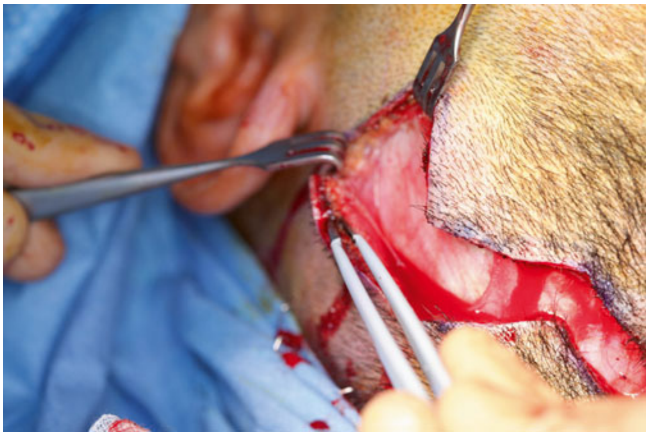

Fig. 16.33 Haemostasis may be achieved in a number of ways. It is the authors' practice to "dry as you go" with bipolar diathermy. However, the use of Raney clips, either loaded manually, or in a "gun dispenser" is quicker

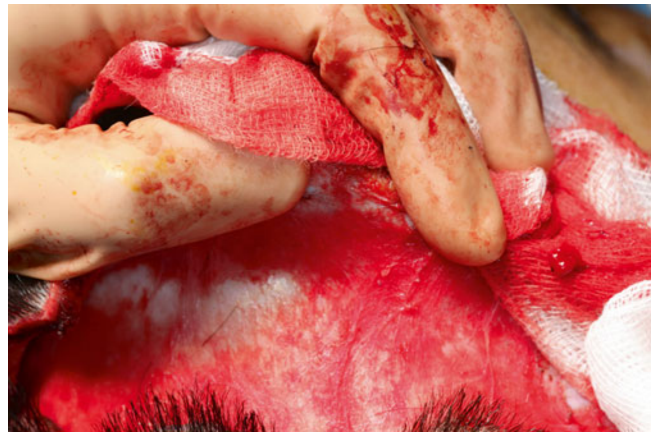

Fig. 16.34 Once incised along the full length, upward and anterior traction demonstrates the fibrous tissue that needs to be incised to get into the subgaleal plane. Sharp dissection is best achieved using a number 10 scalpel

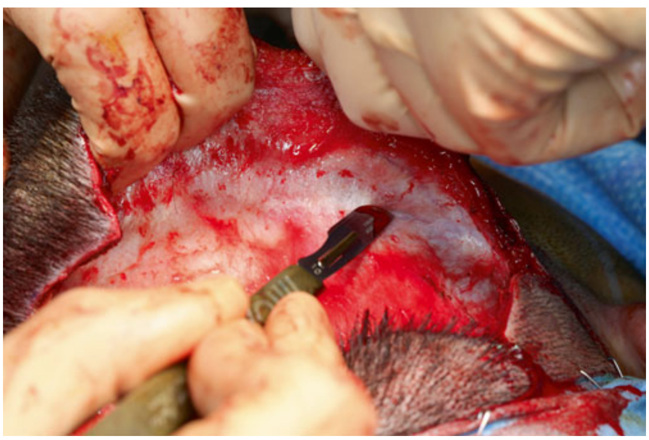

Fig. 16.35 Once in the correct plain, the dissection progresses easily and rapidly. If urgent access is required, it is possible to simply reflect the skin flap forward tearing the soft tissue. However, this results in unpredictable preservation of pericranium. Provided that the incision and dissection is made in the "yellow cranial zone" (see Fig. 16.16), there is little likelihood in involving the facial nerve

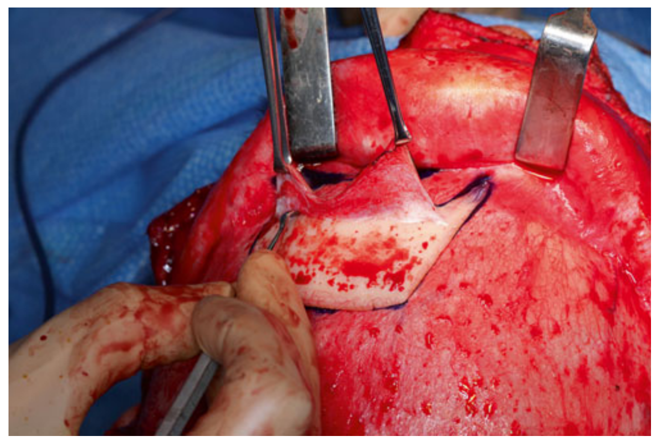

Fig. 16.36 Towards the anterior margin a second, subperiosteal incision is made. The anterior margin of the forehead degloved using a periosteal elevator (a Mitchell's trimmer is ideal for this)

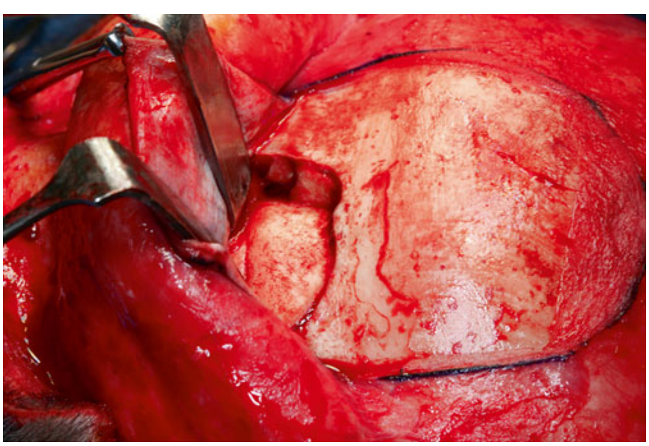

Fig. 16.37 In this case there is an obvious frontal sinus fracture. Should the fragments be loose, then countertraction (in the form of a clip) may be required to prevent pressure on the globe and aid dissection

16.6.1 The Pericranial Flap

This is an extremely useful flap which is usually raised at the same time that the coronal flap is turned down (see also Chap. 13). It is a vascularised pedicled flap which can be used as an additional layer in repairing the anterior cranial fossa, dural tears or obliterating the frontal sinus. If skin has been lost it can also be used to cover any exposed bone and will support a skin graft. Several designs of flap are possible.

16.6.1.1 Anteriorly Based Pericranial Flap

This is very straightforward to raise. The key is to decide very early on (preferably preoperatively), whether a lateral approach is safer. Once the lateral margins are divided you are committed to an anterior flap. Remember that a considerable length of pericranium may be taken from under the occipital flap.

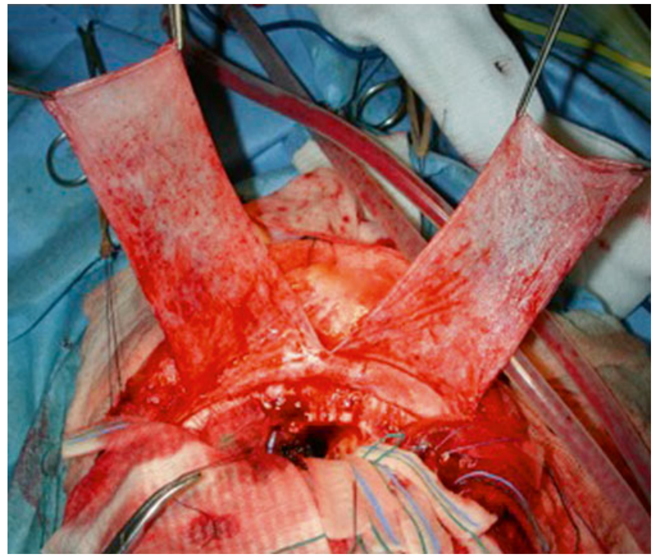

Fig. 16.38 The pericranium may be divided and used for a variety of reasons, including anterior fossa reconstruction, midface suspension, and soft tissue augmentation over multiple plates in patients with thin forehead skin

16.6.1.2 Laterally Based Pericranial Flap

This is extremely versatile and should be considered whenever there is any question of compromise of the anterior pedicle. Most patients with segmentation of the frontal bandeau can be assumed to have such damage.

Case 1

Fig. 16.39 The flap is raised as a bipedicled flap. Following anterior and posterior cuts, very careful use of a Mitchell's trimmer ensures a clean plane of dissection

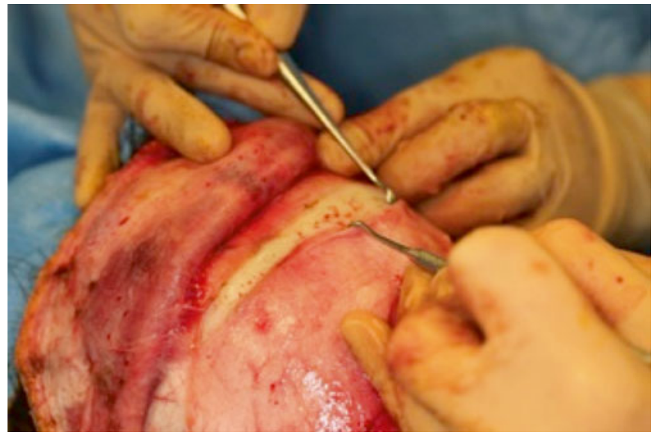

Fig. 16.40 A second surgeon assists raising the flap along a wide front simultaneously. Short movements along the whole width of the bone are the key to minimising tears. A wet swab can be also used to help gently "wipe" the flap up

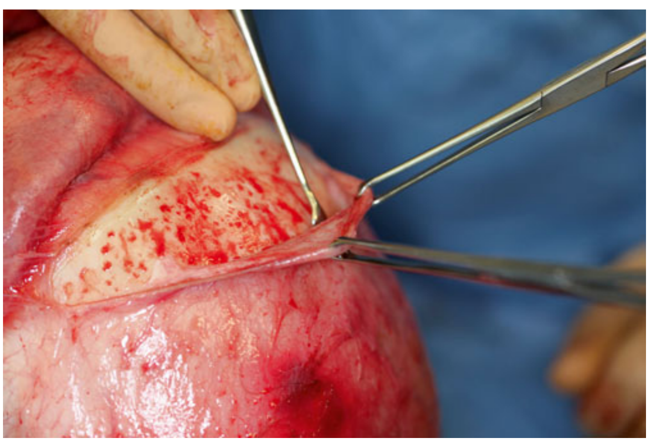

Fig. 16.41 Allis forceps are then placed on the free edge and the pericranium lifted by the assistant, facilitating further dissection

Fig. 16.42 The same procedure is followed posteriorly. Lifting the free edge up displays the plane over the temporalis fascia

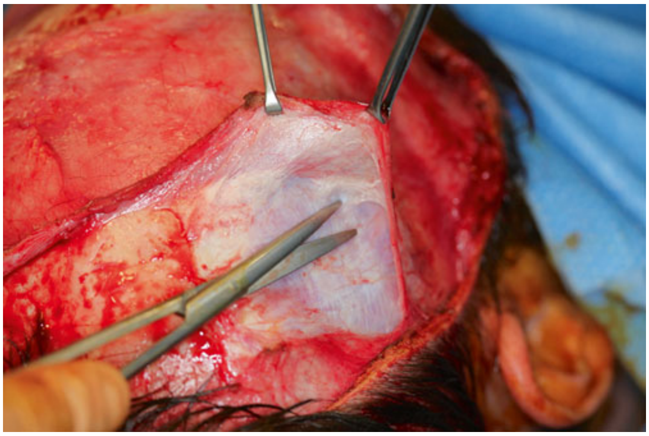

Fig. 16.43 The pericranial and temporal flaps are now developed anteriorly. Gently lifting the fascia allows further dissection

Fig. 16.44 The flap can now be released from whichever side is chosen and lifted up. It is important to divide the superficial temporal fascia behind the landmarks for passage of the temporal branch of the facial nerve

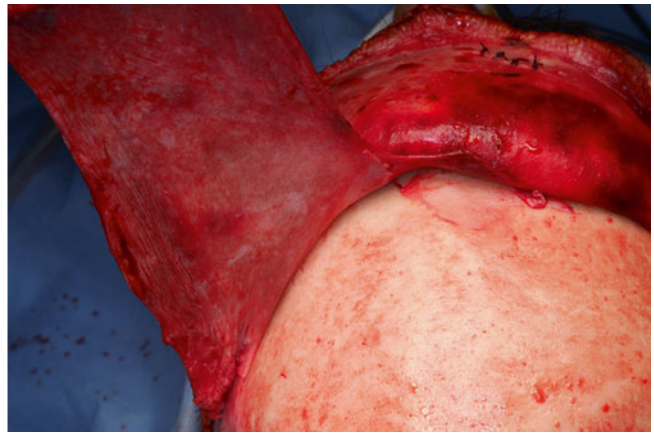

Fig. 16.45 The whole flap can be undermined "off bone" with an elevator. This also allows access to the frontozygomatic suture if required. Note the attempt here to include some collaterals from the anterior pedicle

Fig. 16.46 The pericranium can also be advanced using a backcut placed along the posterior inferior margin

Fig. 16.47 These flaps are very delicate and need to be carefully handled and protected. A saline soaked swab is gently placed

Fig. 16.48 In this instance, the flap has been used in the repair of the anterior cranial fossa. Following meticulous haemostasis and placement of the flap, Surgicel and Tisseal are applied

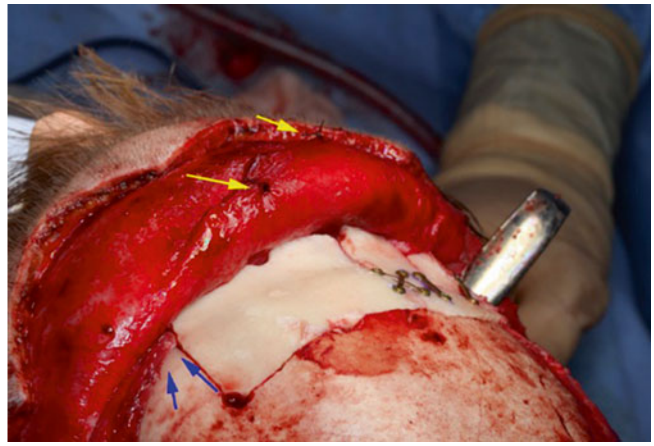

Fig. 16.49 When replacing the cranial bone, it is important to place, or trim it, such that there is a channel for the flap to pass without compression of the pedicle (*blue arrows*). The free edge of the graft has been sutured (*yellow arrows*) to the undersurface of the skin flap. This prevents inadvertant "pulling away" of the graft during late manipulation of the flap during closure

Case 2

Fig. 16.50 In this case the extent of major injury is seen clinically (marked panda eyes, telecanthus, loss of nasal projection and orbital dystopia). There is also an anterior open bite

Fig. 16.51 The three-dimensional CT confirms the clinical diagnosis. The comminution of the frontal bandeau is highly suggestive of damage to the anterior pedicles of the pericranium

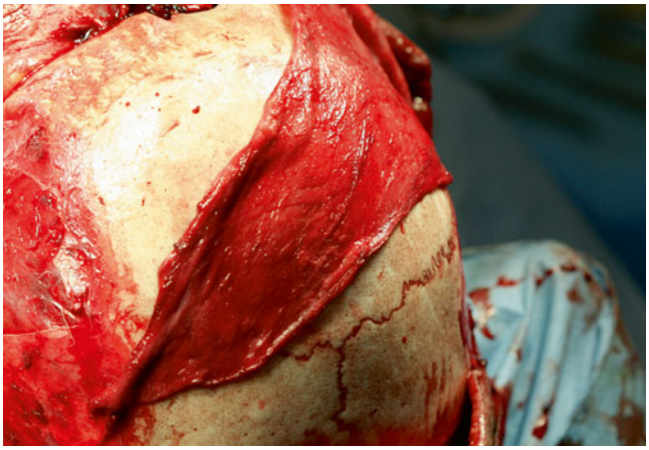

Fig. 16.52 The laterally based pericranial flap is raised and mobilised as illustrated in case 1

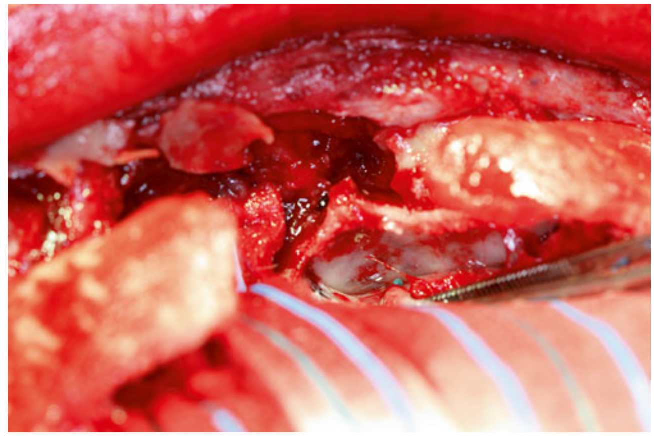

Fig. 16.53 Following disarticulation of the frontal bandeau fragments, the extent of skull base disruption becomes evident. Disarticulation allows safe anterior cranial reconstruction together with accurate superomedial orbital wall repair. The next stage is to remove the posterior frontal sinus wall with rongeurs and formally cranialise the sinuses. It is important to ensure adequate removal of sinus lining

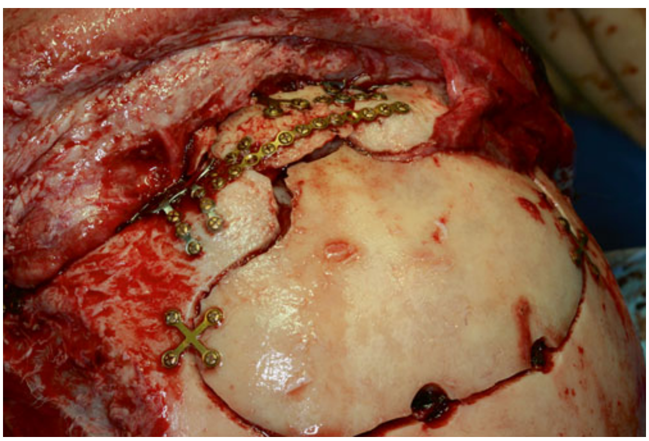

Fig. 16.54 The bandeau is then repaired, with the pericranium "letterbox" fed into the anterior cranial fossa on the right side. The NOE repair has been pedicled off the bandeau

Fig. 16.55 The postoperative CT scan

16.7 Frontal Craniotomy

This is generally a neurosurgical procedure, but is illustrated here to helps us understand what is required. This is a potentially dangerous procedure as there is a risk of tearing the sagittal venous sinus when making the bone cuts.

Case 1

Fig. 16.56 Following exposure of the skull, the site of the craniotomy is marked. The position of the superior sagittal sinus is also marked. Paramedian burr holes are drilled using a round burr

Fig. 16.57 The dura mater is quite robust and can be seen at the base of the burr hole

Fig. 16.58 The bone is then cut using a craniotome which is introduced via the burr hole. This has a metal sheath covering the tip of the drill. As the device is passed through the bone, the sheath strips off the dura in advance of the drill, thereby protecting it and minimising dural tears. However, dural tears can still occur and need repair. The last cut of the craniotome is between the two burr holes posteromedially. That way if the sagittal sinus is entered, the flap can be quickly removed

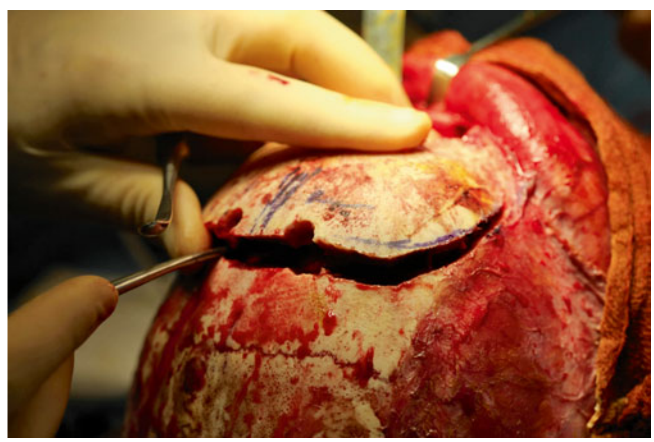

Fig. 16.59 The craniotomy is then lifted off. There may be some resistance anteriorly if there is residual intact posterior sinus wall. The flap is readily fractured off and placed safely in damp gauze

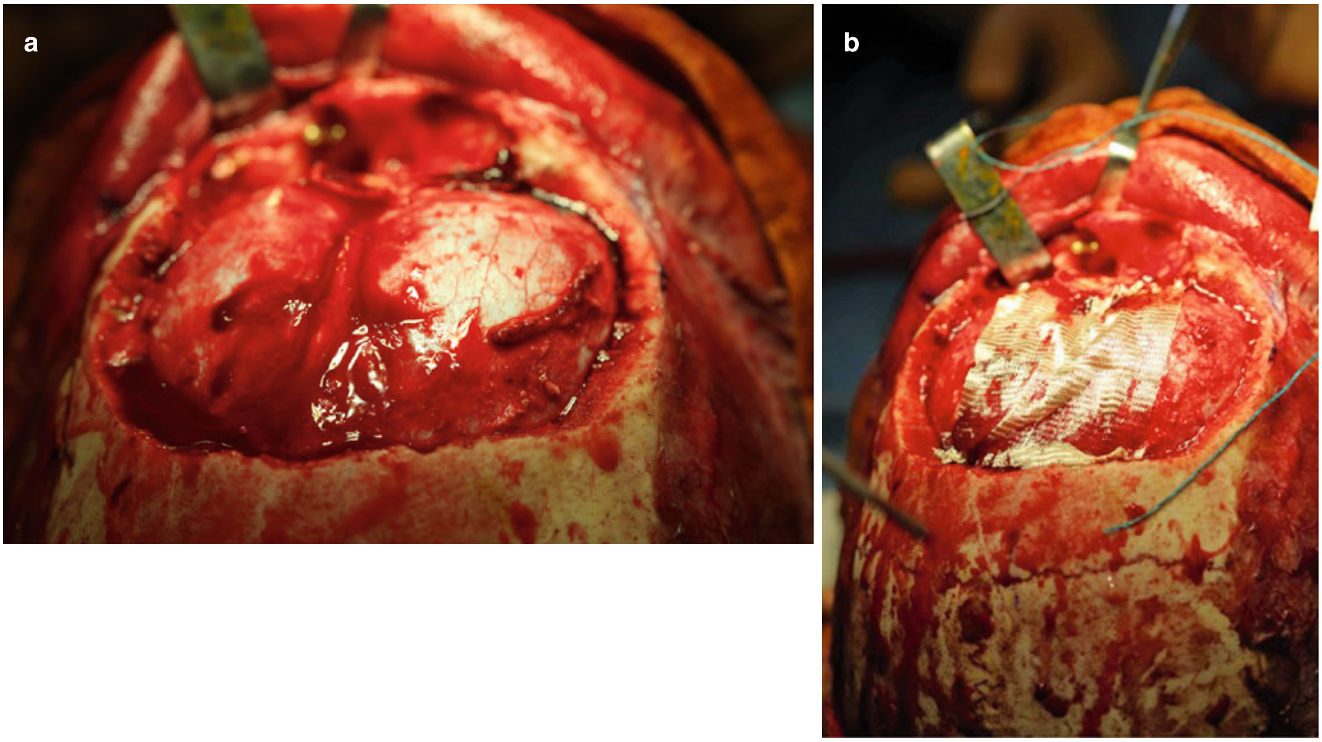

Fig. 16.60 Following removal of the bone flap, haemostasis is obtained. There may be troublesome ooze from the small veins overlying the sagittal sinus, or from the sinus itself. Fortunately these respond well to Surgicel, and neurosurgical patties soaked in saline (**a**, **b**). A useful tip is to suck on the soaking patty rather than directly on the surface of the dura (or brain). Dural tears are then repaired as necessary

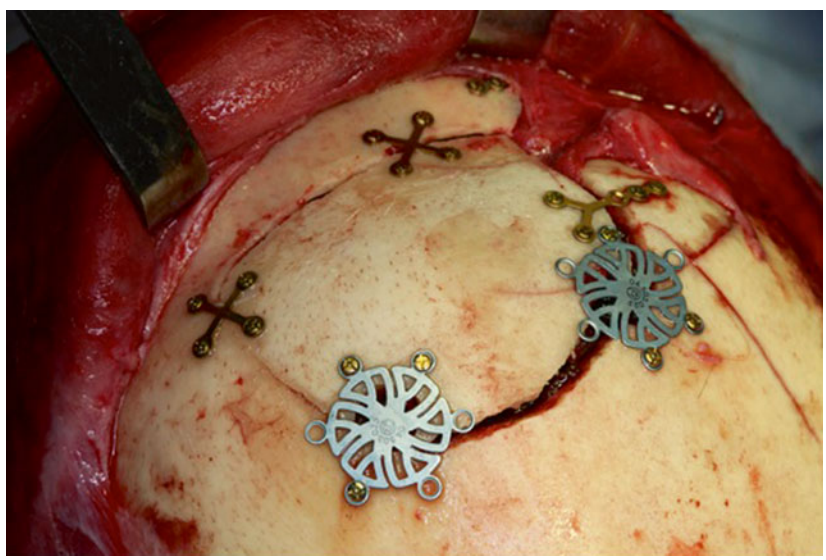

Fig. 16.61 When closing, the craniotomy burr holes can be covered using specially designed plates. Burr holes can be visible in patients with thin scalps postoperatively

Case 2

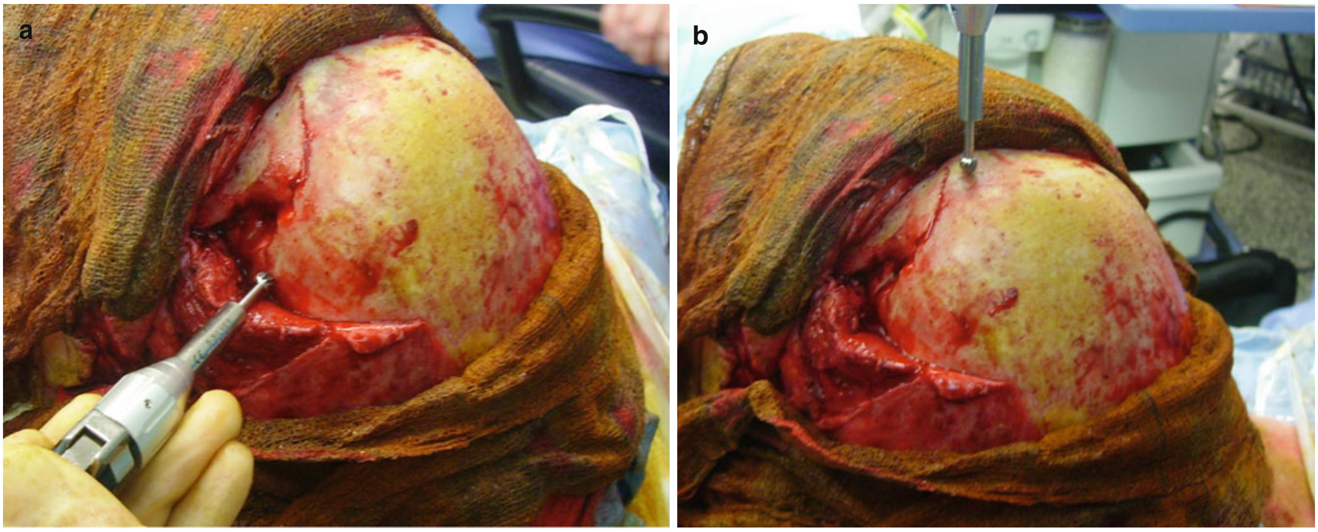

Fig. 16.62 With more lateralised injuries, a lateral craniotomy may be required. This follows the same sequence as case 1, but with this approach there is no risk to the sagittal sinus (**a**, **b**)

Case 3

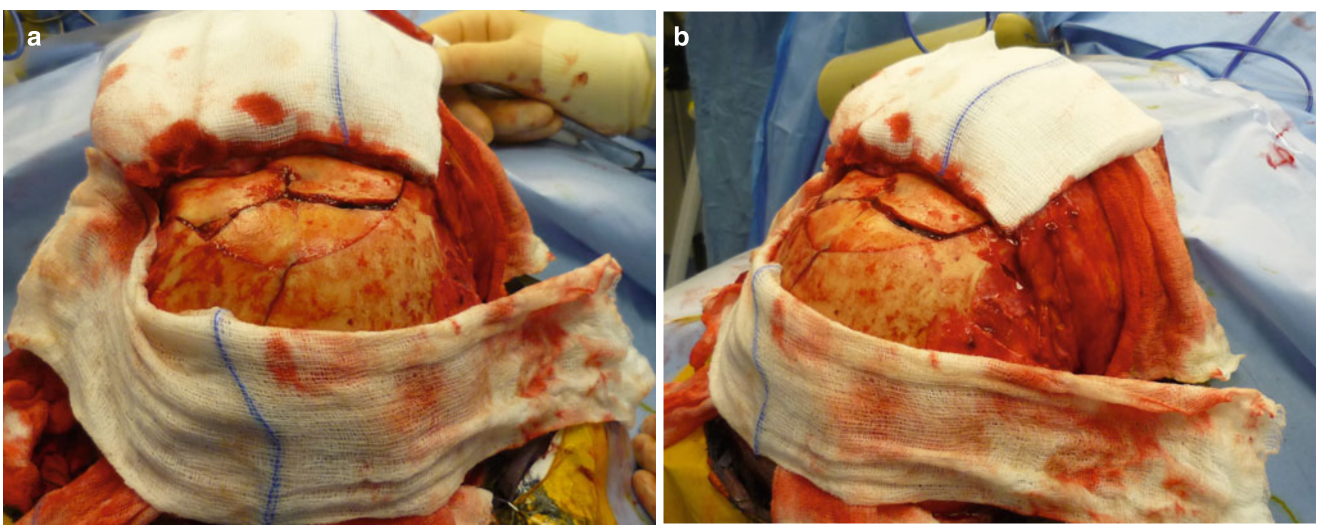

Fig. 16.63 In this case the patient had sustained major injuries following an alleged assault with a baseball bat. On raising the coronal flap there was immediate fracture diastasis with highly mobile fragments. This is not a good sign. It is due to the swollen brain pushing the fragments apart (**a**, **b**)

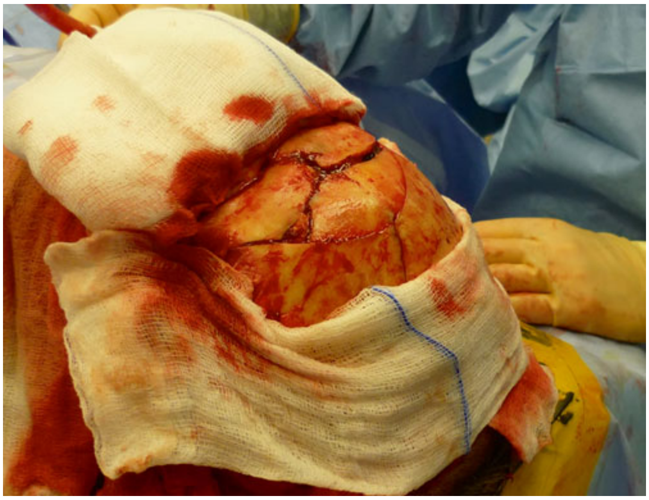

Fig. 16.64 The fractures were incorporated into the design of the craniotomy and supplementary bone cuts made

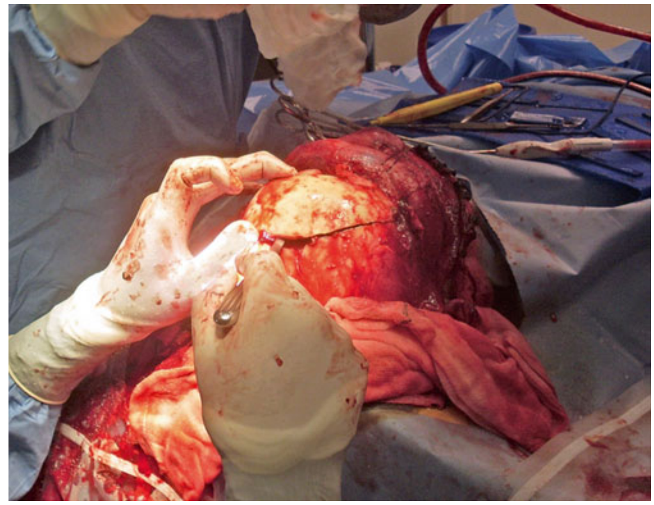

Fig. 16.65 The bone fragments were then cautiously raised

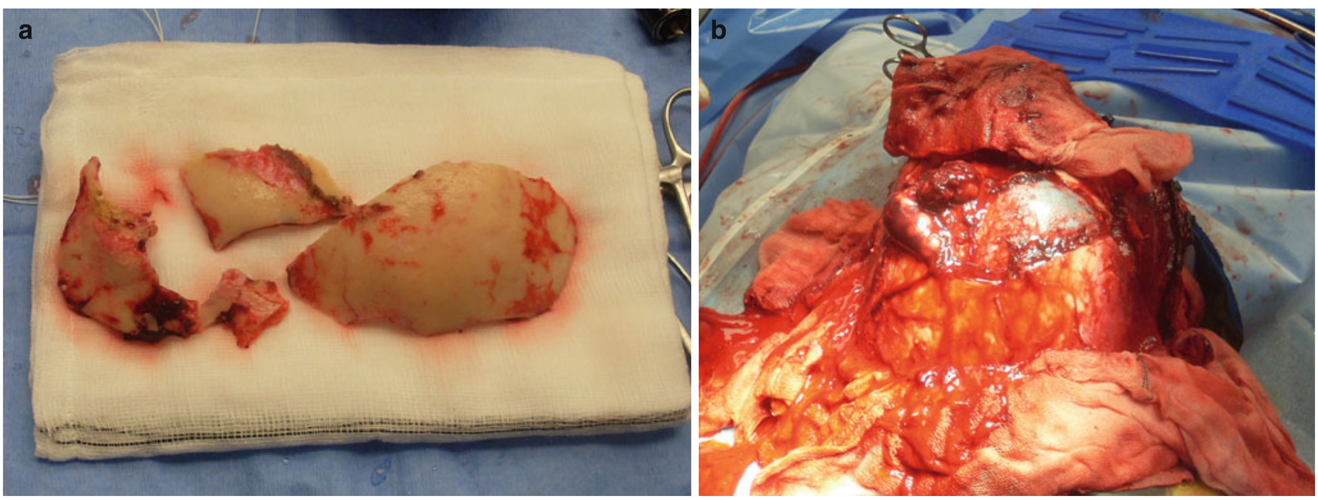

Fig. 16.66 All fragments were set aside in preparation for extracorporal repair. There was extensive brain swelling. Brain can be seen here herniating out through a dural tear (caused by the fractures). In cases of significant brain swelling, the bone is usually not replaced but stored (sometimes in the patient's abdominal wall) and replaced at a later date when the ICP has come down

16.7.1 Harvesting Inner Table Bone Graft

The inner table of a cranial bone flap is extremely useful in fracture repair. This can be harvested synchronously while the neurosurgeon is managing the intracranial compartment. By using the inner bone there is no risk of iatrogenic skull fracture and no postoperative contour defect.

Fig. 16.67 The defect is measured using a foil suture packet, which has been cut to shape and used as a template

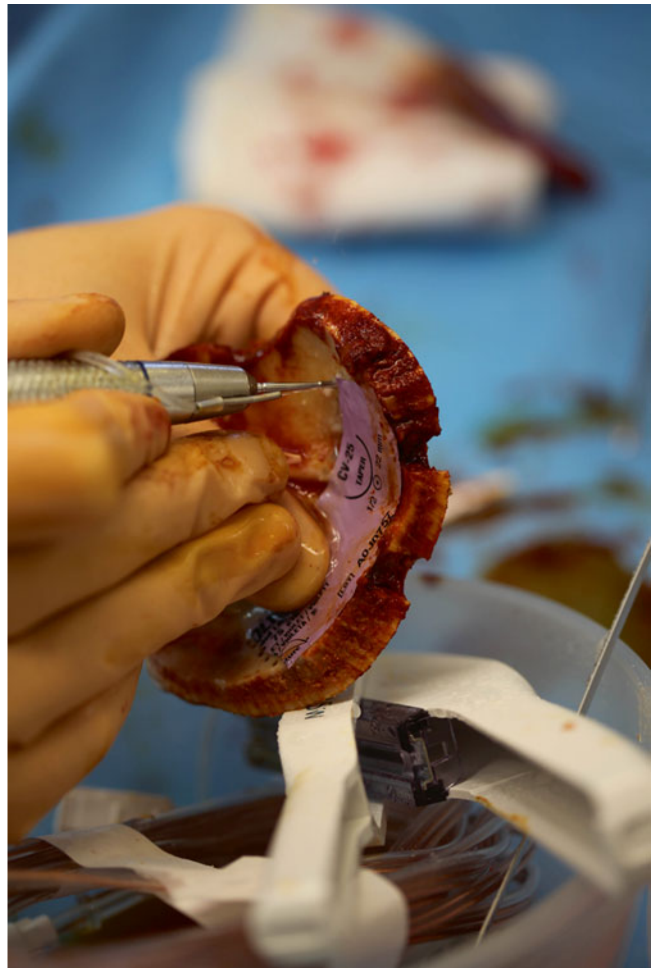

Fig. 16.68 The graft is usually harvested from the posterior region of the bone flap. This is because the inner and outer tables fuse anteriorly, making them much more difficult to separate. A burr is used to cut around the template, drilling through the internal table into the cancellous space. The cut must be fully through the inner table along the entire graft margins

Fig. 16.69 Three and 5 mm osteotomes (preferably flexible and thin) are then introduced and gently tapped through the cancellous bone. It is important to pass these along the margin on a wide front. Alternatively a drill can be used. Once nearly mobilised, the osteotome can be rotated gently, fracturing the remaining bridging cancellous bone

Fig. 16.70 The cut surface of the donor site can be seen here. This can be curetted to obtain further cancellous bone slurry

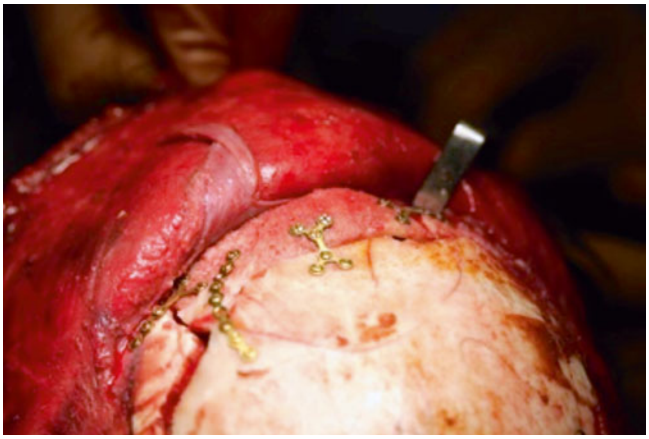

Fig. 16.71 The graft can be contoured and fixed into the recipient site with miniplates

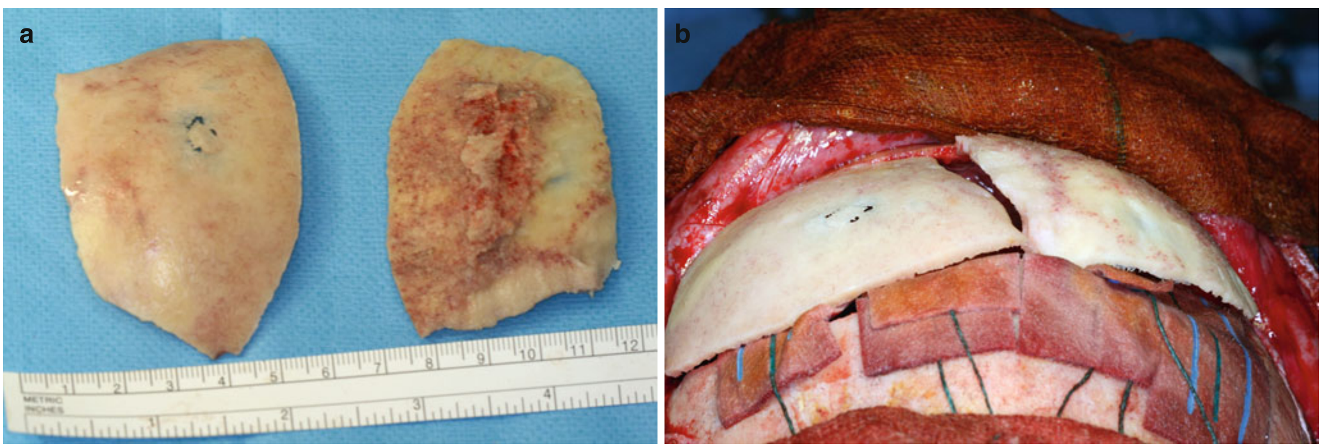

Fig. 16.72 Large grafts are possible. In this case the entire inner table has been harvested to replace the right half of the frontal bone (**a**, **b**)

16.8 Orbital Roof Repair

Orbital roof repair can be technically demanding. These injuries may be a direct continuation of a fracture pattern involving the frontal sinus, bandeau and zygoma, or they may occur in isolation, particularly in those patients with an absent frontal sinus. Not all fractures need repair. If there is no dystopia or troublesome pulsation of the globe, some surgeons may elect to observe the patient. Often the fracture will heal and the bone remodels.

Case 1

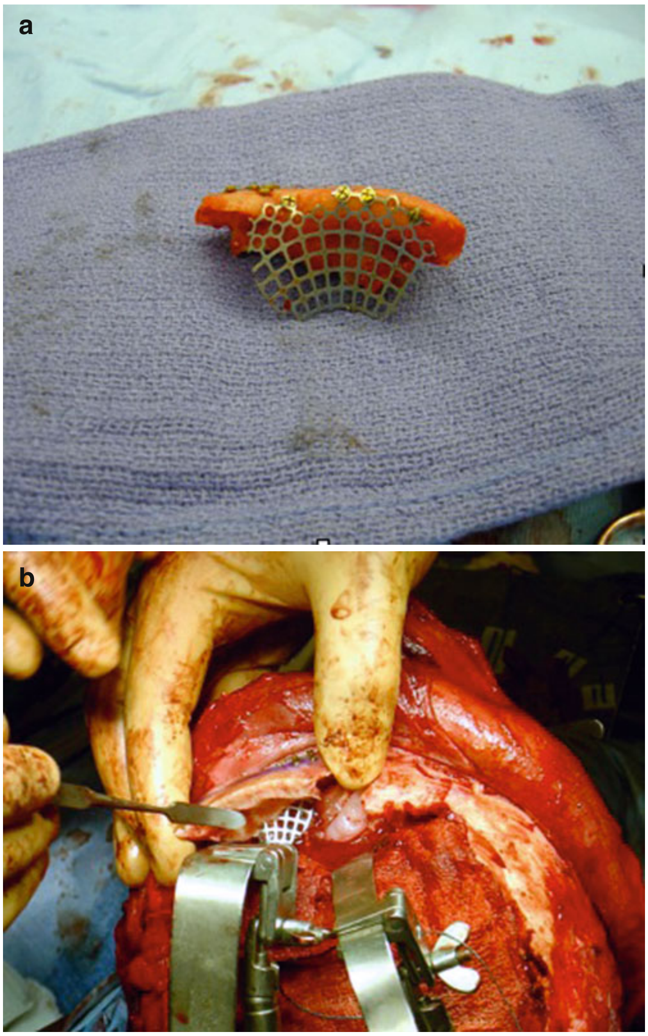

Fig. 16.73 Conceptually these fractures are approached in the same way as the frontal bandeau; i.e., if in doubt remove the section and plate ex vivo (**a**, **b**)

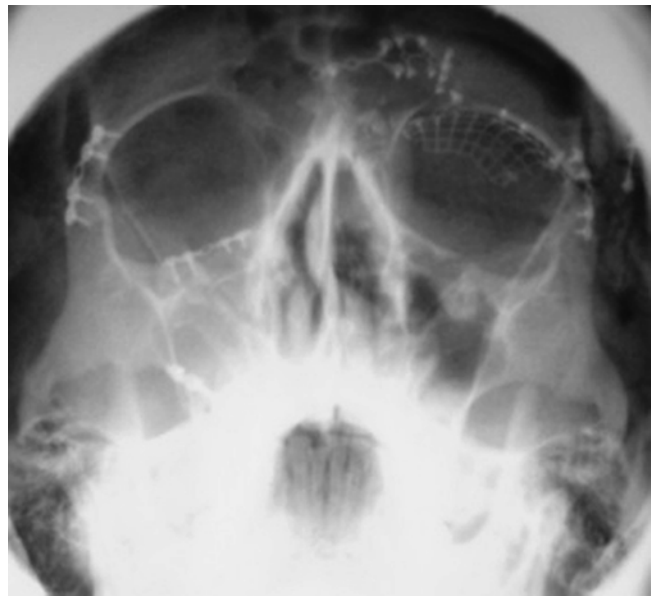

Fig. 16.74 In this case, the segment of bone including the rim was removed, the defect measured and replaced with a plate. The defect was relatively small, and straightforward to reconstruct

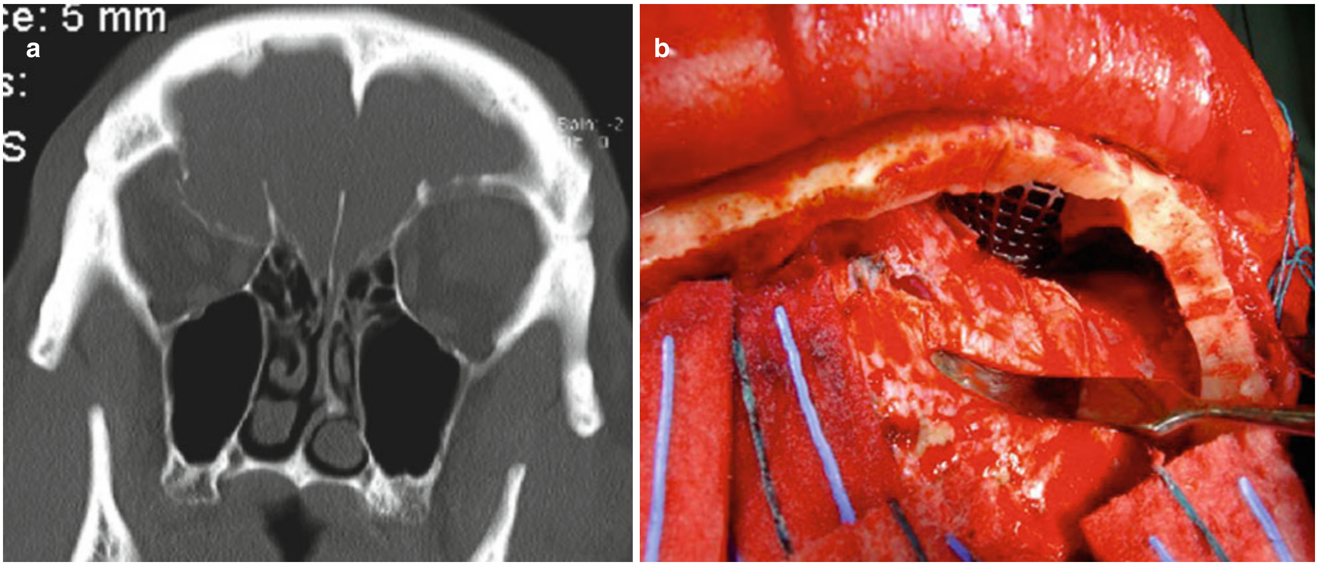

Fig. 16.75 In this case the frontal sinus was absent and the superomedial wall fracture was isolated. The patient had pulsatile exophthalmos and dystopia. In such cases the bone is often comminuted. The defect may be better repaired with mesh following disarticulation (orbitotomy) of the supraorbital rim (**a**, **b**)

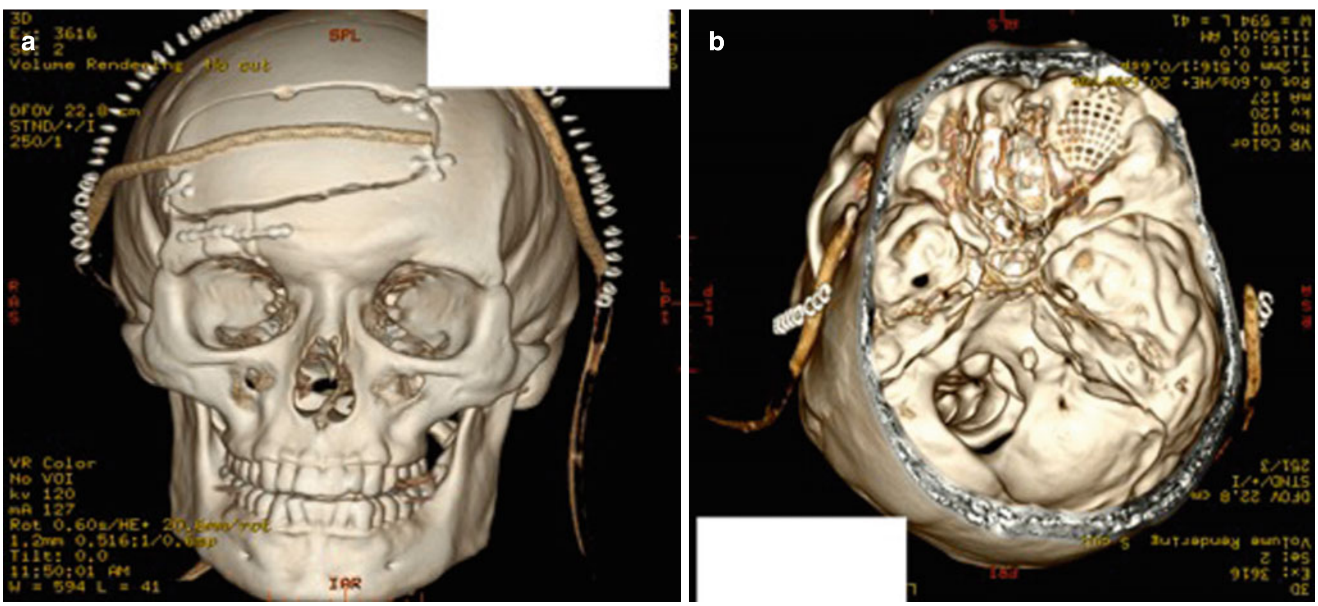

Fig. 16.76 Postoperative imaging demonstrates the reconstruction and the rim plates following the orbitotomy (**a**, **b**)

16.9 Frontal Bandeau Repair/ Reconstruction

This is a key component in repair of craniofacial injuries. Errors in repair at this site will be conveyed to the rest of the face (notably transverse width and projection). It is therefore important that this contour is precisely repaired or reconstructed, not only for cosmetic reasons, but also to ensure a strong foundation for the nasoorbitoethmoid (NOE) complex and the middle third of the facial skeleton.

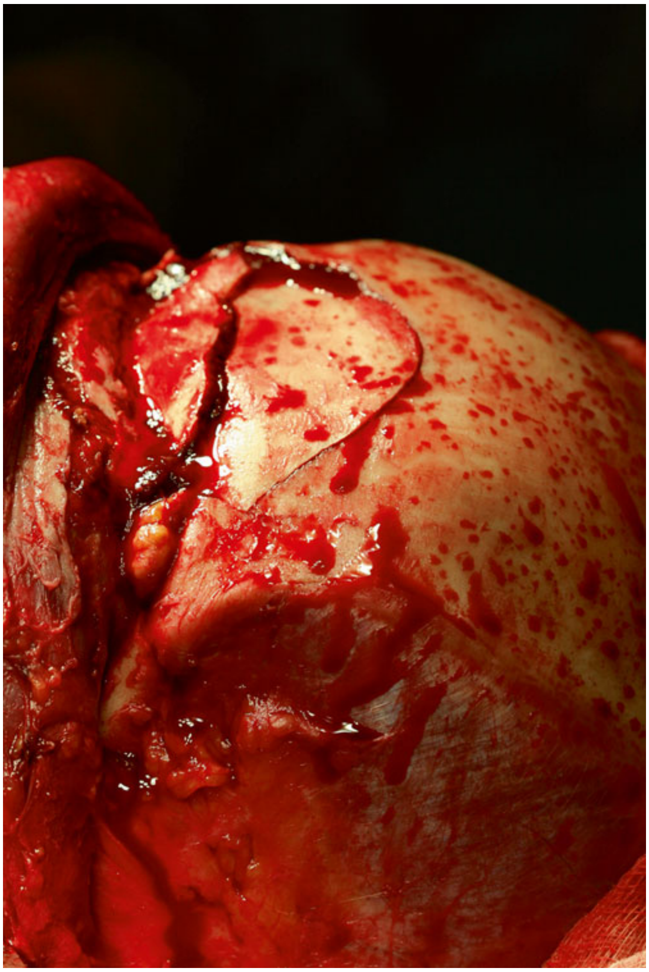

Fig. 16.77 This case illustrates the importance of the bandeau as the interface between the upper third of the face, naso-orbital-ethmoid region, orbital roof, and the lateral zygomatic complex. Flattening of the entire region is seen

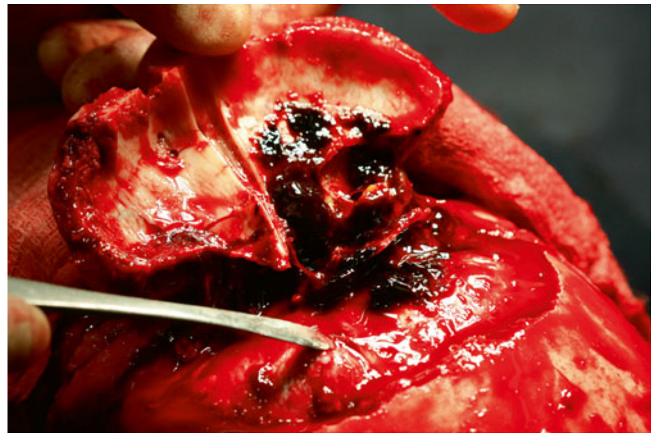

Fig. 16.78 Following craniotomy the extradural haematoma is evacuated. Mobile fragments are carefully removed and placed on the surgical trolley (in their correct orientations)

Fig. 16.79 Without losing orientation, the bone fragments can then be assembled (extracorporal repair). Both sides of the bones are viewed to ensure accurate apposition

Fig. 16.80 Following cranialisation and haemostasis, the reassembled bone is replaced and fixed with 1.3-mm miniplates. The inherent flexibility of this system allows some "wiggle room" when replacing the fragments

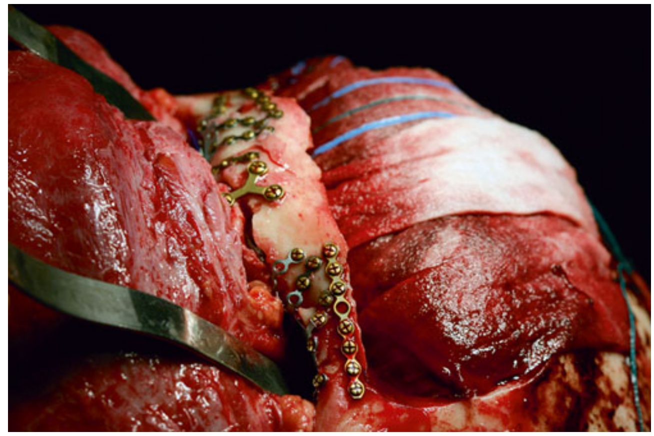

Fig. 16.81 The rest of the repair then proceeds. Each successive step in the repair must be verified as anatomically correct

Fig. 16.82 Close up view of the left supraorbital rim. The orbital roof has been reconstructed with an orbital roof plate

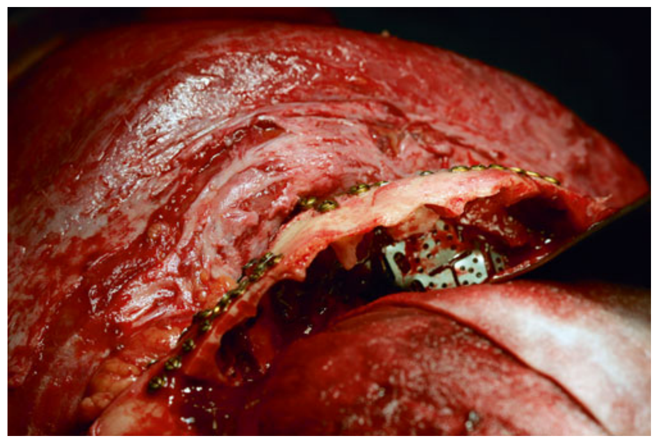

Fig. 16.83 A view into the anterior cranial fossa. The right orbital roof plate can be seen. The anterior cranial base is then covered with a lateral pericranial flap and fibrin glue placed over the bone graft

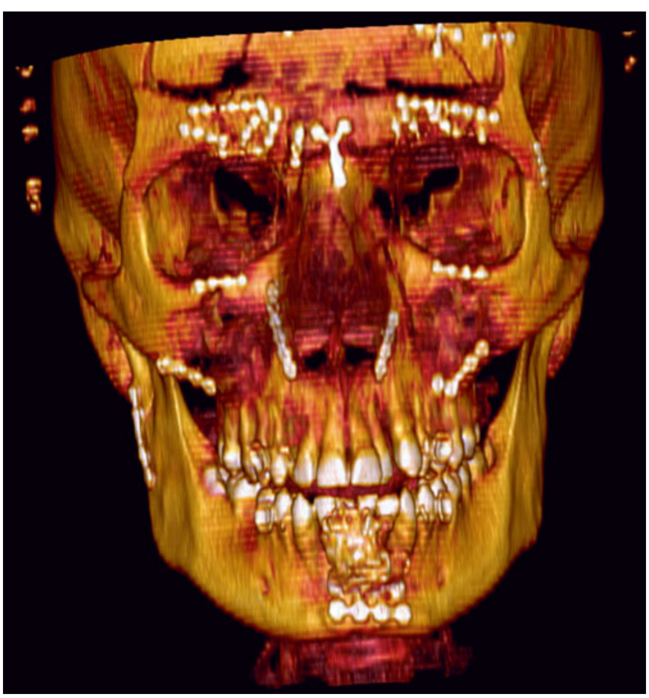

Fig. 16.84 The full reconstruction at lower, middle and upper third are seen. There is a whitehead's varnish pack over the symphyseal fracture

16.10 Lateral Temporal Extension (Exposure of the Temporal Bone)

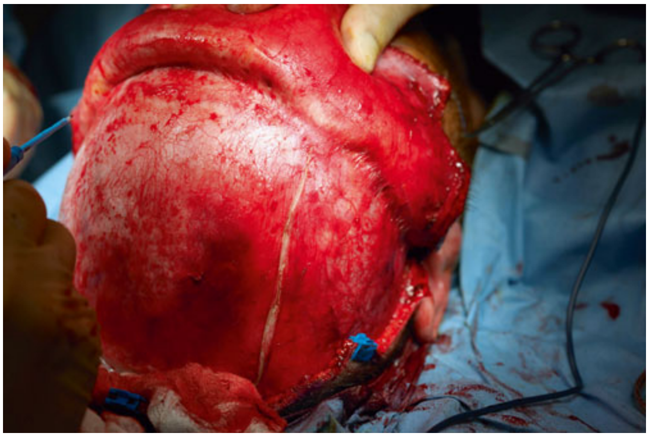

Fig. 16.85 Following coronal and temporal dissection the temporalis muscle is identified. A cuff of muscle and periosteum must be left attached to the superior temporal line. Monopolar diathermy is commonly used

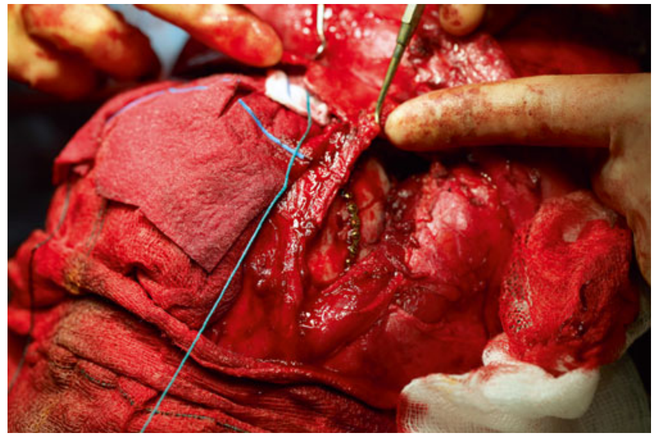

Fig. 16.86 An incision is made 2 cm below the muscle insertion, and the muscle carefully stripped off the temporalis bone. The cuff of muscle can be seen here; note the plating of the squamous temporal bone fracture

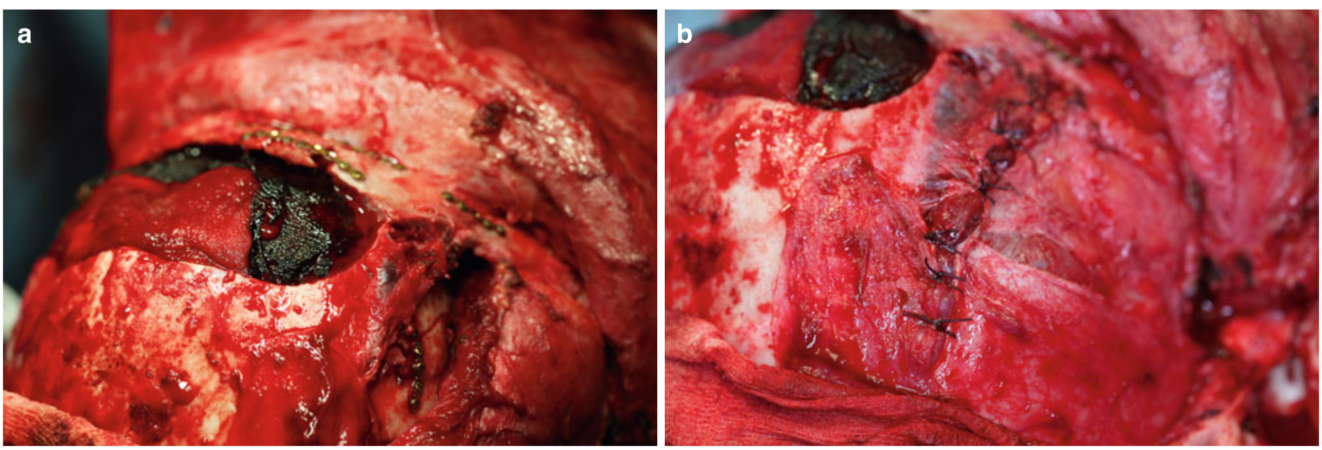

Fig. 16.87 Following repair the muscle flap is resuspended using a 3/0 vicryl passed through the superior muscle and periosteal attachment. Multiple interrupted sutures are required (**a**, **b**)

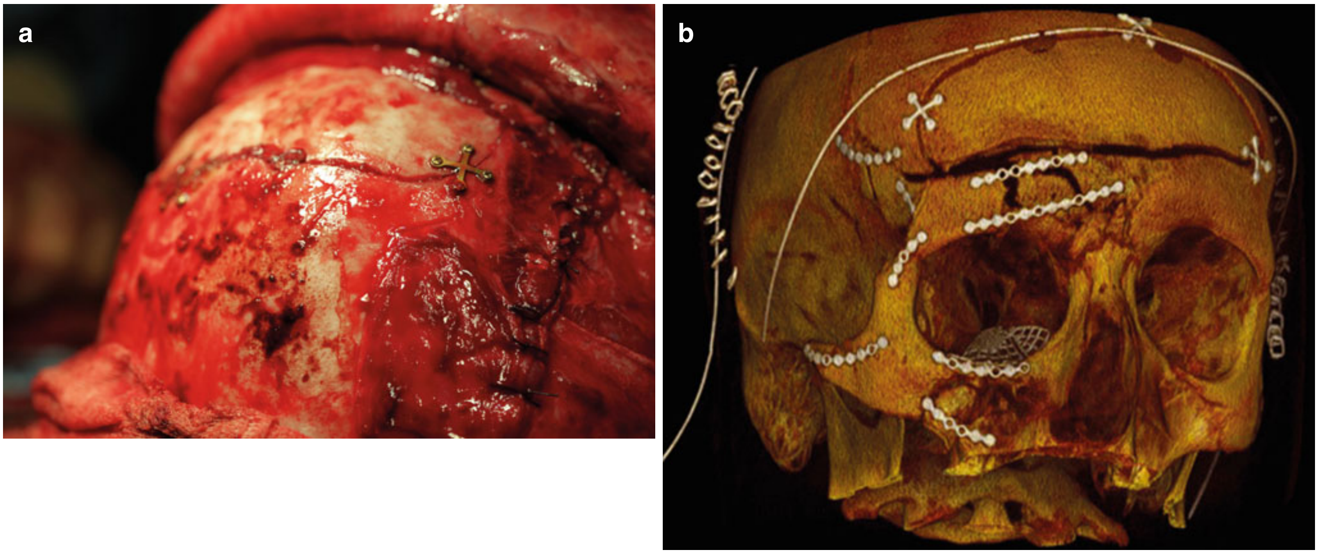

Fig. 16.88 Total repair prior to closure and postoperative three-dimensional (3D) CT scans. These show the full extent of the repair. Temporal bone repair was required to facilitate supraorbital projection, accurate positioning of the zygoma and orbital floor plating. The zygomatic buttress was also repaired (**a**, **b**)

16.11 Frontal Sinus Fractures

Frontal sinus fractures are commonly seen following high-energy craniofacial trauma, although relatively low energy, but localised impacts, can fracture large sinuses. Either way, the principles used in their management remain the same. However, management of the frontal sinus is a controversial topic. This is partly because none of the treatments are totally free of risk. Indeed, some complications although uncommon, are very severe and potentially life-threatening. These include CSF leak and meningitis, encephalitis, mucocele, empyema of the sinus, brain abscess, osteomyelitis, cavernous sinus thrombosis and meningoencephalocele.

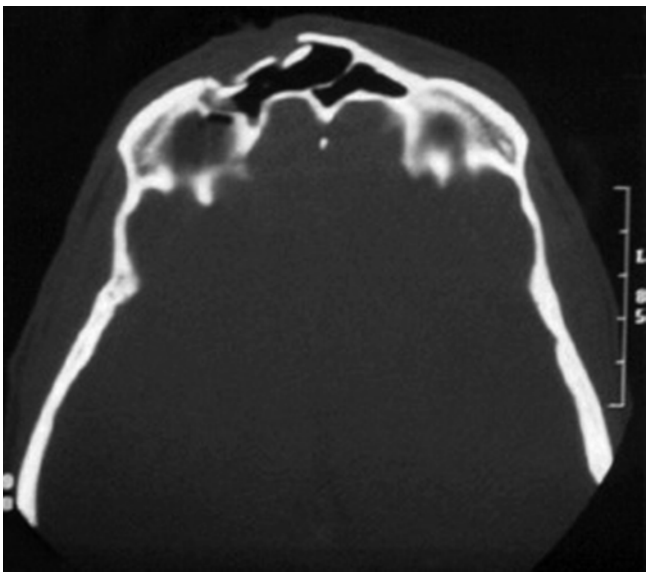

Fig. 16.89 Type 1 frontal sinus fracture

The main issues when managing these fractures are the prevention of meningitis and prevention of mucocele formation. Meningitis becomes a concern when the posterior sinus wall and dura have both been breeched—bacteria can then pass from the nasal cavity, through the sinus, into the CSF. The risk of mucocele formation arises when free drainage of the sinus is impaired. These complications can occur decades after the original injury and therefore long-term follow-up is ideally required, although this may not be practical.

With isolated fractures of the anterior wall of the frontal sinus, the issue is a cosmetic one. The patient then has a choice of either undergoing primary repair of the fracture, or waiting until it has healed and having secondary correction if required. With minor displacement of the anterior sinus wall, this second option is not unreasonable. Very often the residual deformity is not as severe as initially anticipated and secondary correction can be undertaken relatively easily and through a much smaller incision.

16.11.1 Classification of Frontal Sinus Fractures

There are several classifications which attempt to describe the local anatomy and help plan management. Conceptually a simple system involving anterior and posterior tables and combinations thereof provides a useful guide to surgical treatment and prognosis.

16.11.1.1 Type 1: Anterior Table Only

These fractures are common. The fracture may extend across the frontal bar and involve the supraorbital rims or nasoorbitoethmoid complex. These injuries are prone to secondary deformity depending on the size and displacement of the fracture and thickness of the overlying soft tissues. Surgical

complexity increases with comminution, and thin bone may require alloplastic or autogenous reconstruction, rather than direct repair.

16.11.1.2 Type 2: Posterior Table

These are more unusual injuries, as it is difficult to fracture the posterior wall, yet leave the anterior wall undamaged. These may be associated with NOE complex fractures, where the impact was not directly on the forehead. The decision to treat these is based on the amount of displacement of the posterior table and the size of defect. This is a controversial area in management with different thresholds for intervention. The presence of intracranial air indicates a dural tear and communication with the nose and sinuses. However, some surgeons will elect to observe these on the basis that these layers will heal and the air will resorb.

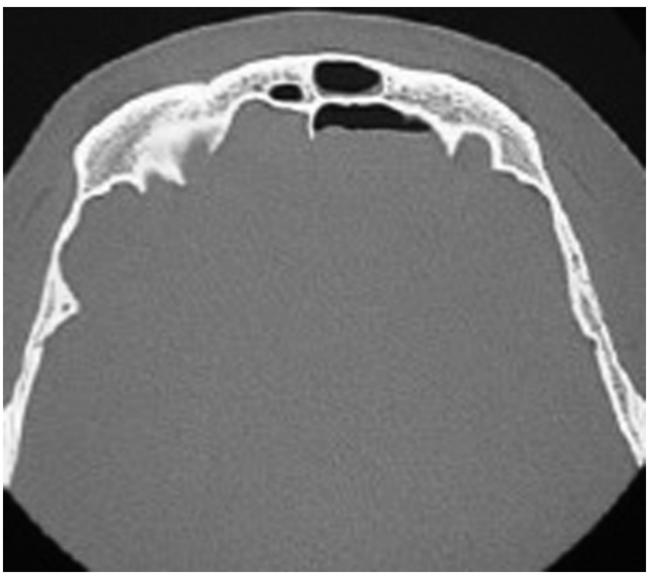

Fig. 16.90 Type 2 frontal sinus fracture. Intracranial air is evident. The fracture (not seen on this view) was lower down and associated with a NOE fracture

16.11.1.3 Type 3: Anterior and Posterior Tables

In these fractures there is a direct extension of the anterior wall fracture across the sinus to include the posterior wall. The significance of this fracture is the inference of an escalation in energy transfer. This in turn will indicate likely tears of the dura and involvement of the drainage system. Management involves the combined elements of both anterior and posterior table fractures.

Fig. 16.91 Type 3 frontal sinus fracture

16.11.1.4 Type 4: Through and Through

This type of injury represents the most challenging group. In addition to the fractures there is significant injury to the overlaying soft tissue envelope which must be carefully addressed. This is illustrated later.

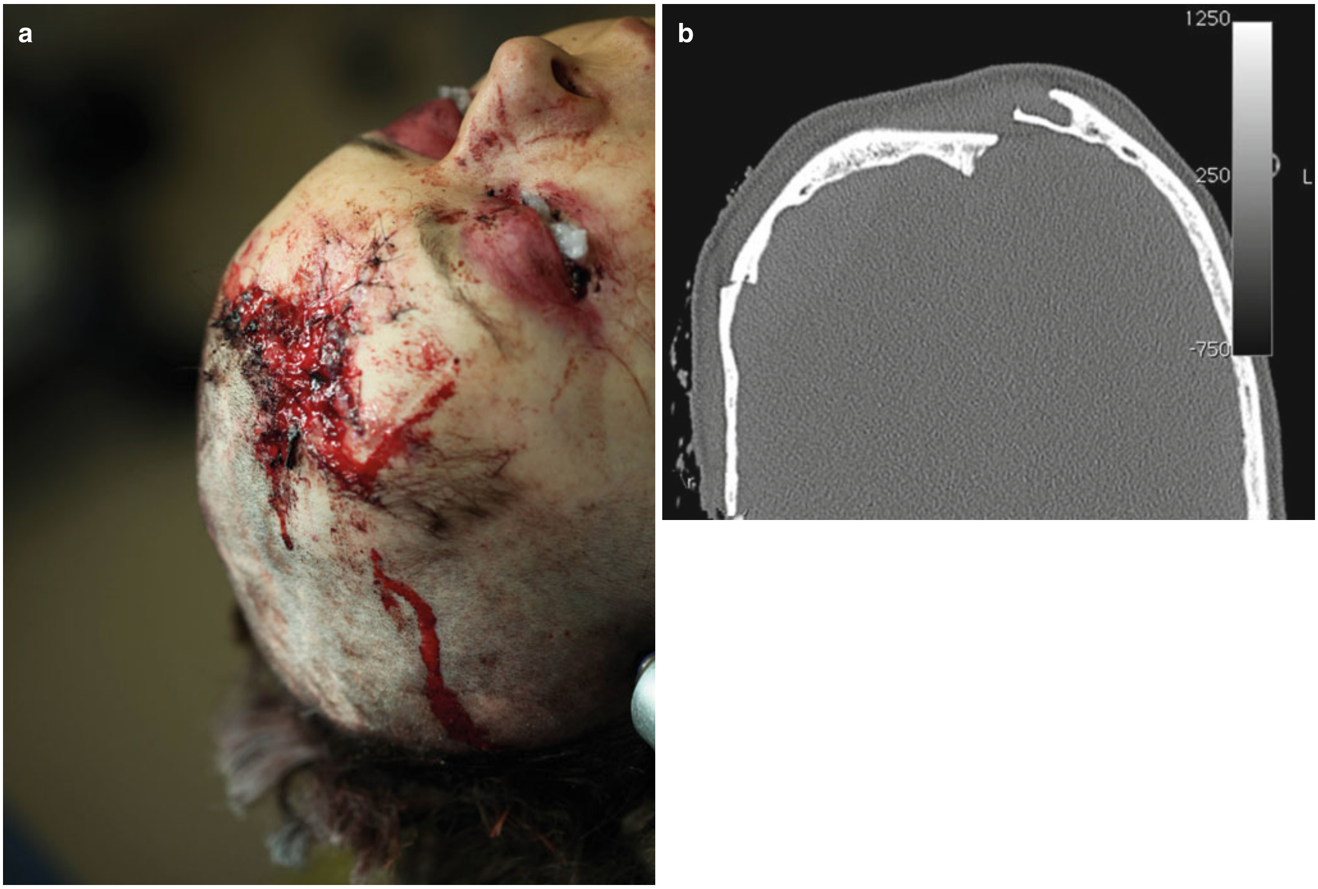

Fig. 16.92 Type 4 frontal sinus fracture (**a**, **b**)

16.11.2 Treatment Aims in the Management of Frontal Sinus Fractures

These can be summarised as follows:

1. Establish a "safe sinus:" no risk of infection or mucocele formation
2. Protect the intracranial contents
3. Prevent early and delayed complications
4. Restoration of aesthetics
5. Functional and anatomical integration with other anatomical territories: NOE, midface, orbital roof and upper medial orbital wall

16.11.2.1 Anterior Sinus Wall Fractures (Type 1)

The decision to operate and the type of procedure required depends on a number of factors.

1. Degree of displacement
2. Degree of comminution
3. Thickness of anterior table
4. Involvement of adjacent bony anatomical regions
5. Presence of overlying soft tissue injury
6. Thickness of soft tissue envelope
7. General status of patient
8. Patient's preference

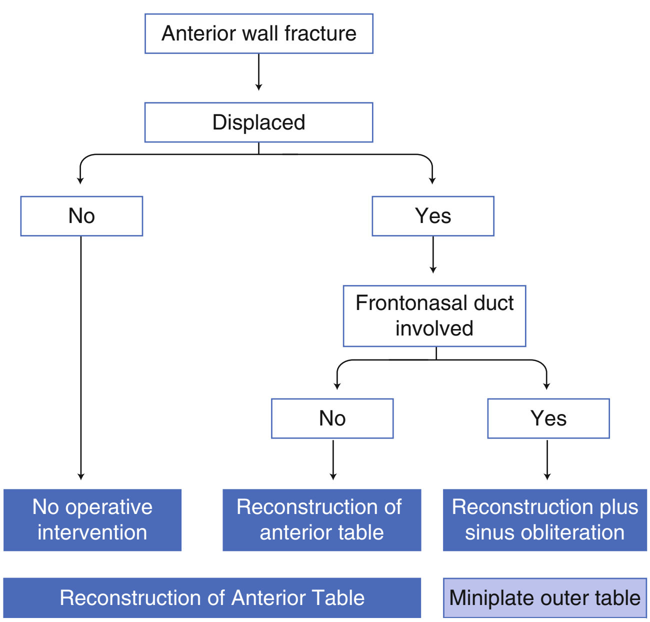

Fig. 16.93 Management of Type 1 sinus fractures (anterior wall)

A practical algorithm is as follows. However, there are alternatives. For example, some surgeons argue that if drainage from the frontonasal duct can be re-established, then sinus obliteration is not necessary.

The choice between repair and reconstruction depends on the thickness of the bone and presence of adequate-sized fragments to plate. With anterior wall fractures, the decision to operate for cosmetic reasons is relative, depending on a balance of risks and benefits. The thickness of overlying soft tissues, shape of defect, and degree of displacement are all important considerations. Around 3 mm of displacement will produce a defect visible to casual observation; but only the patient can decide if this is significant enough to warrant the risks of general anaesthesia and repair.

Repair of the Anterior Sinus Wall

Successful repair of the anterior wall of the frontal sinus has been reported using endoscopic techniques, although this requires specialist expertise and equipment. Alternatively, direct access to the anterior wall is possible through a number of incisions. The coronal flap provides excellent access but is more time-consuming than a direct approach. In the examples shown here, direct access to the fractures has been made through suitable forehead skin creases. Although this is a much smaller procedure it carries the risk of more visible scarring and injury to the sensory nerves of the forehead. Nevertheless, some patients may prefer this to the prospect of a coronal flap. Due to its restricted access, repair of extensive fractures through this incision can be difficult. Careful evaluation of the fracture configuration is therefore necessary. This approach is best suited for simple localised fractures.

In the first case, a midline cutaneous approach was taken using a T-shaped incision sited in suitable obvious skin creases. This provided excellent access to the central forehead and bridge of the nose. Following a full-thickness skin incision, the underlying muscles were carefully divided to expose the underlying periosteum and fracture. Removal of the fragments of the anterior wall allowed inspections of the sinus cavity and confirmation of patency of the frontonasal duct. All three soft tissue layers were carefully closed following repair of the wall.

Overlaying lacerations may also be used to gain access to the anterior wall. These may need extension along a favourable skin crease, but the remainder of the dissection is as previously outlined.

Case 1

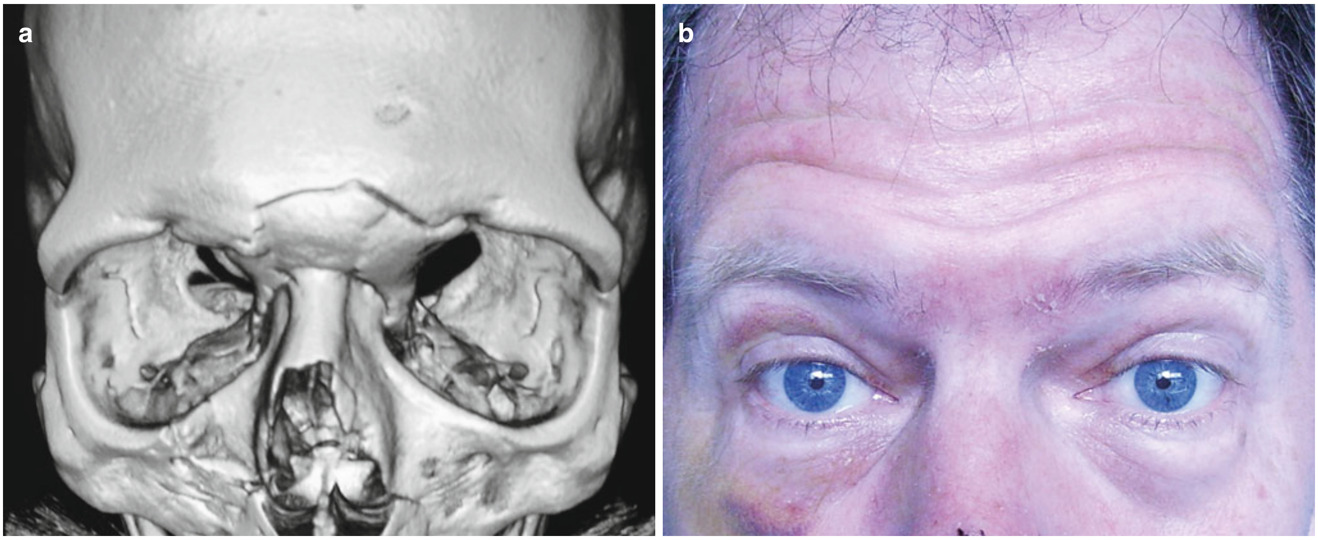

Fig. 16.94 Three-dimensional CT demonstrates a localised depression in the anterior wall. This has resulted in a significant deformity which the patient requested be repaired. The presence of obvious skin creases made this fracture amenable for a transcutaneous repair (**a**, **b**)

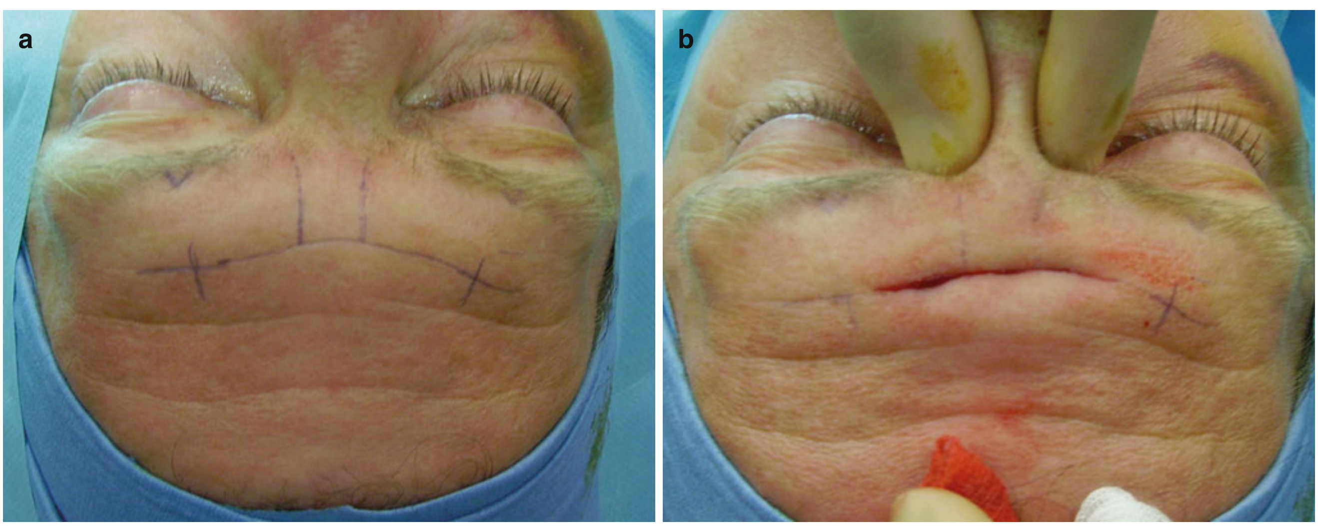

Fig. 16.95 The incision was marked along with several lines of extension (along other creases) (**a**). A full-thickness skin incision was then placed (**b**)

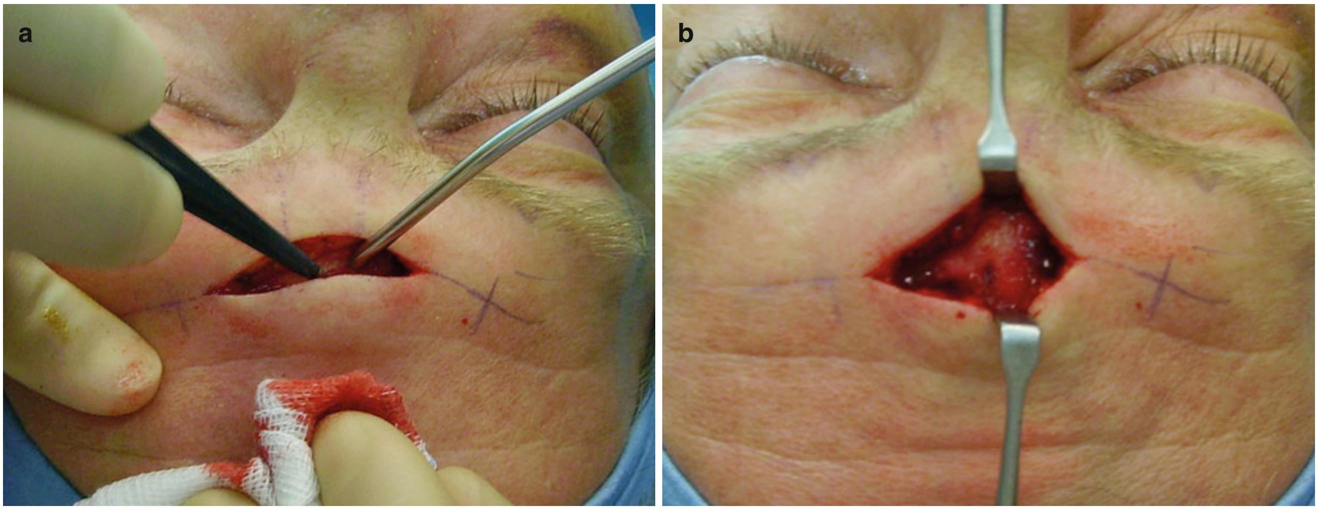

Fig. 16.96 The underlying muscle fibers were carefully separated to expose the periosteum (**a**, **b**)

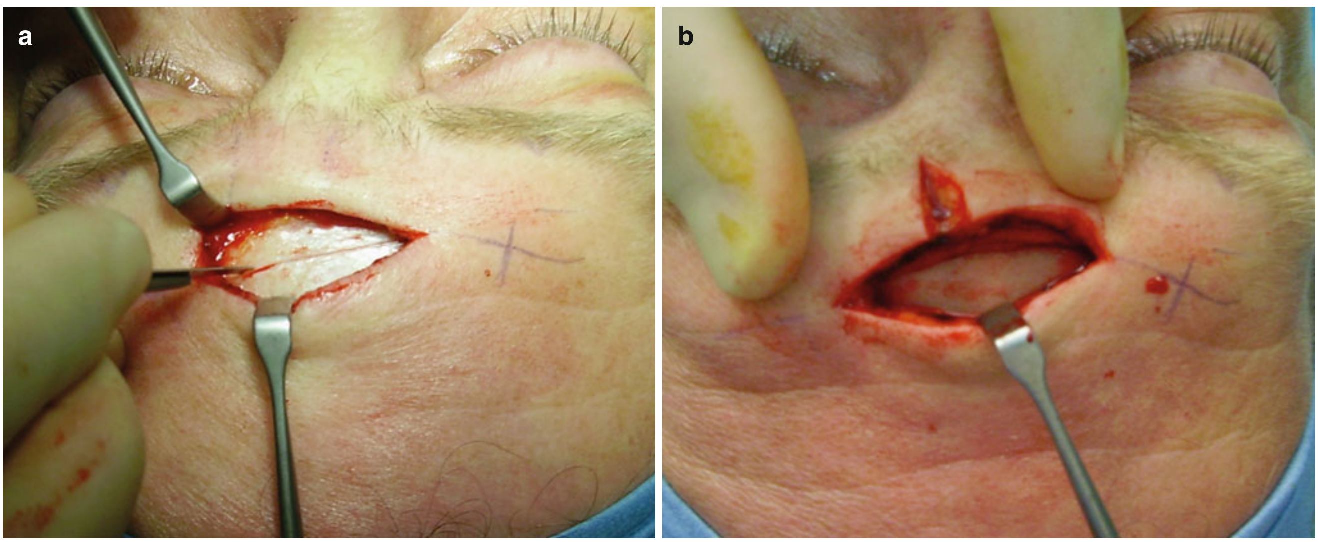

Fig. 16.97 The periosteum was incised and elevated (**a**). Note the additional skin incision to improve access (**b**)

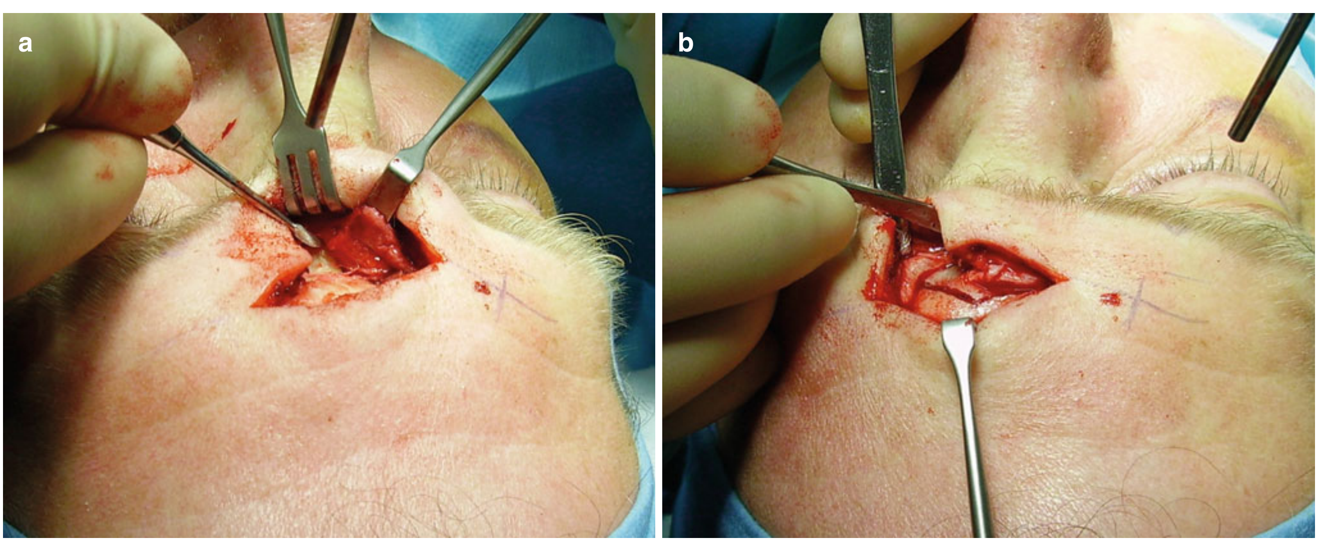

Fig. 16.98 The entire fracture complex was gradually exposed (**a**, **b**)

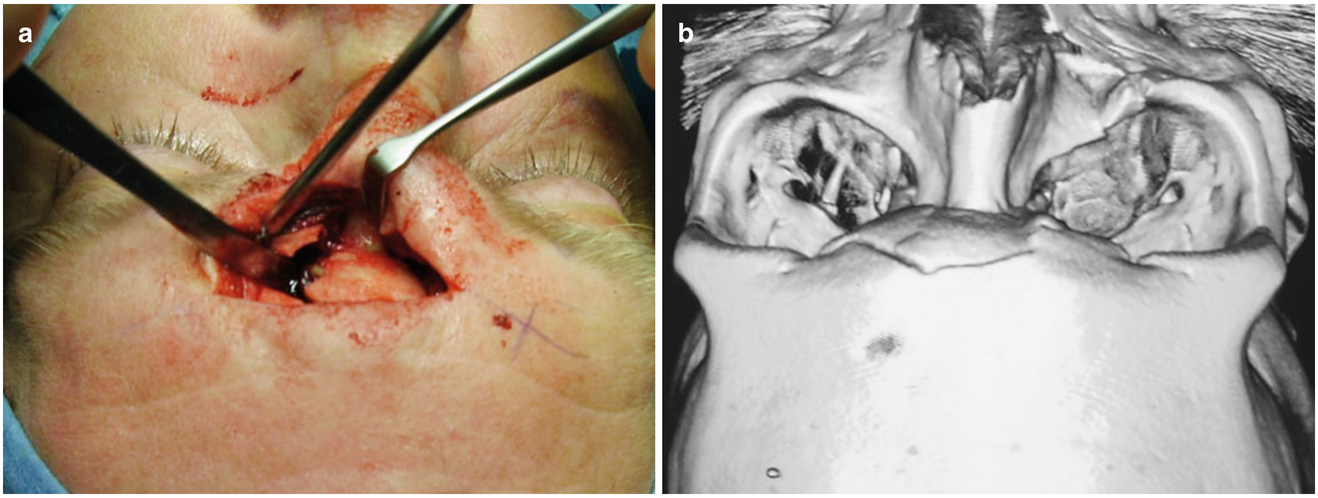

Fig. 16.99 Comparison of the patient (**a**) with the 3D scan (**b**) shows the true extent of displacement

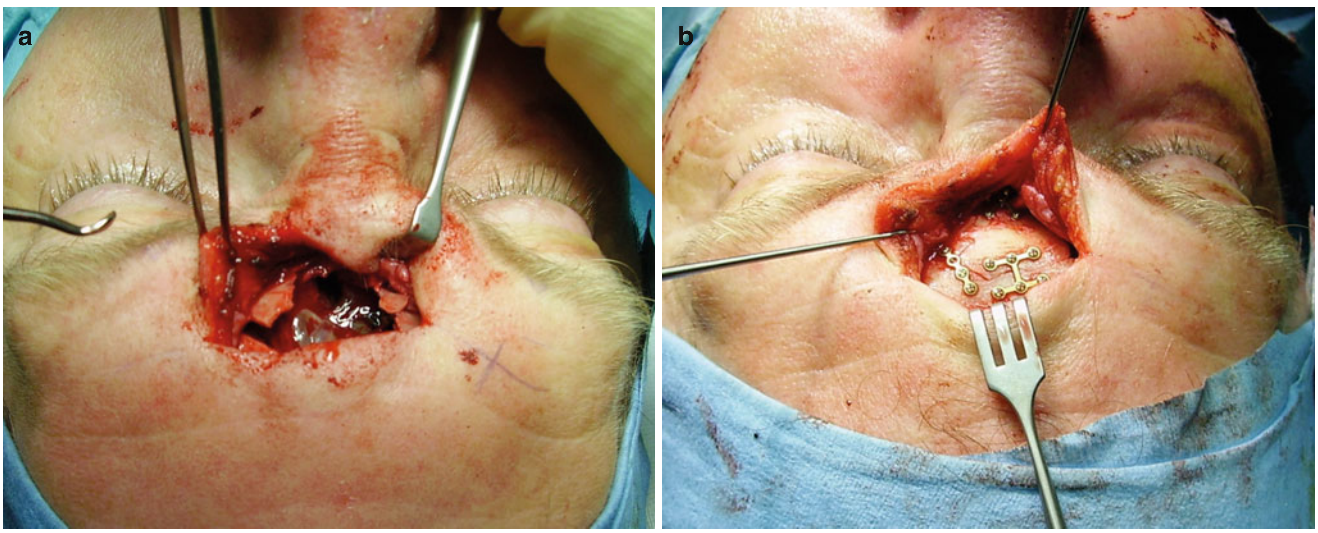

Fig. 16.100 The fragments were carefully elevated (**a**). These were placed on a "sticky-pad" maintaining their spatial arrangements. Following inspection of the sinus and frontonasal duct the fragments were replaced and repaired (**b**)

Fig. 16.101 The wound was closed in layers

In the next two examples, a more lateral approach was undertaken due to the more lateral position of the fractures. The incision can be placed in a suitable skin crease or just above the hairline of the eyebrow, depending upon the superior extent of the fractures. With this approach, branches of the supraorbital nerve are more likely to be encountered and damaged by dissection or traction. These require protection throughout surgery to minimise the risks of postoperative numbness.

Case 2

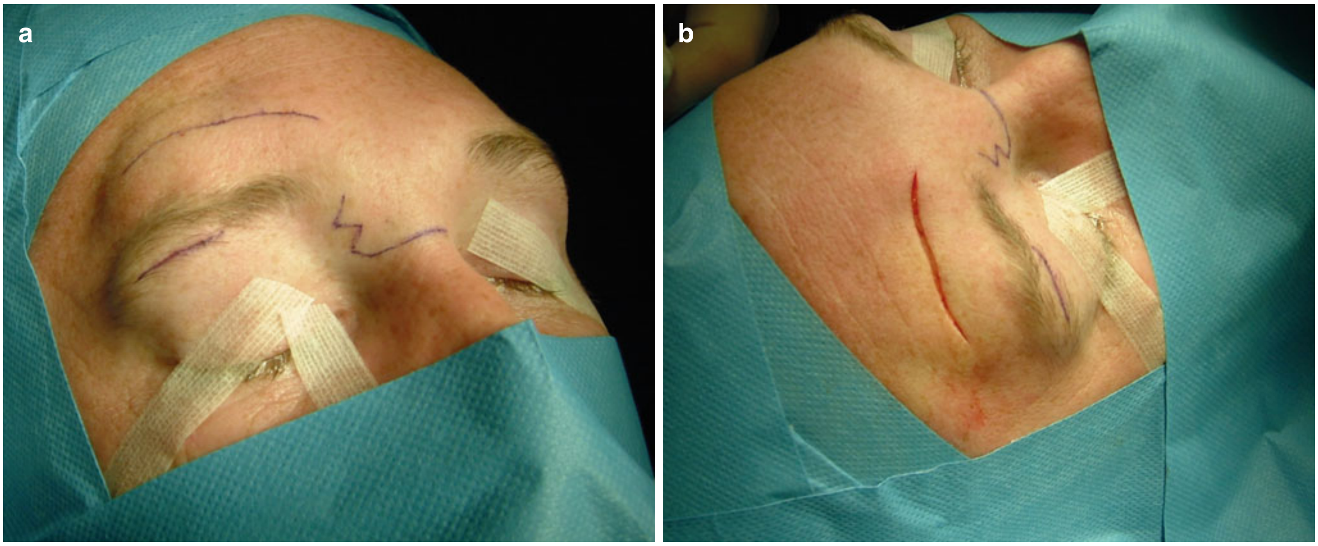

Fig. 16.102 A selection of incisions were marked preoperatively (**a**), utilising local skin creases. The forehead incision was then made (**b**)

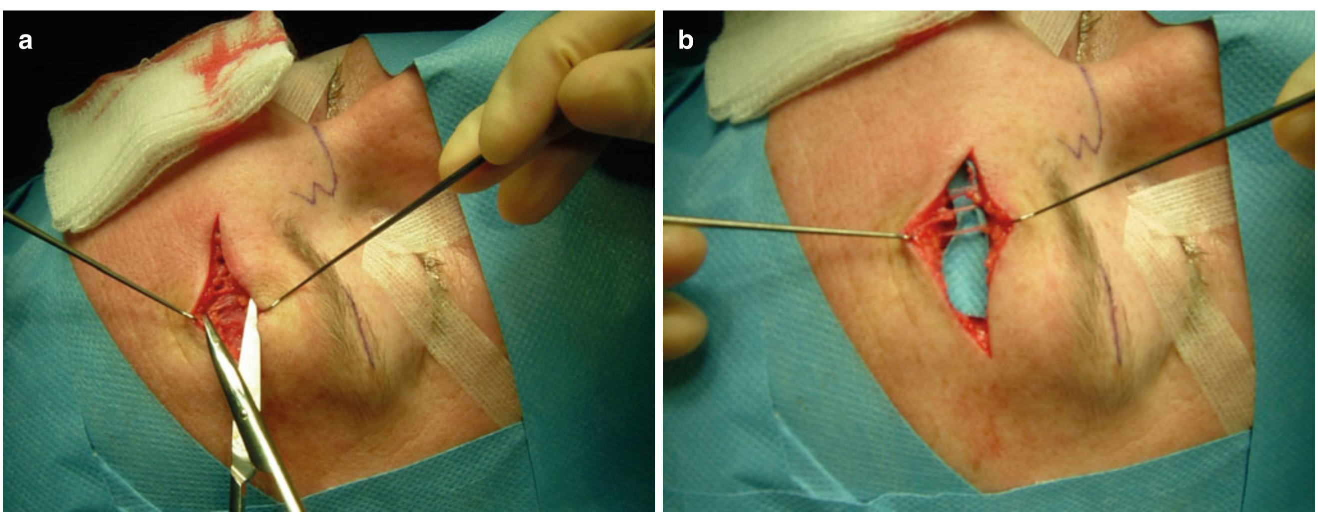

Fig. 16.103 Following full-thickness skin incision, the tissues were carefully separated (**a**). Branches of the supraorbital nerve were quickly identified (**b**)

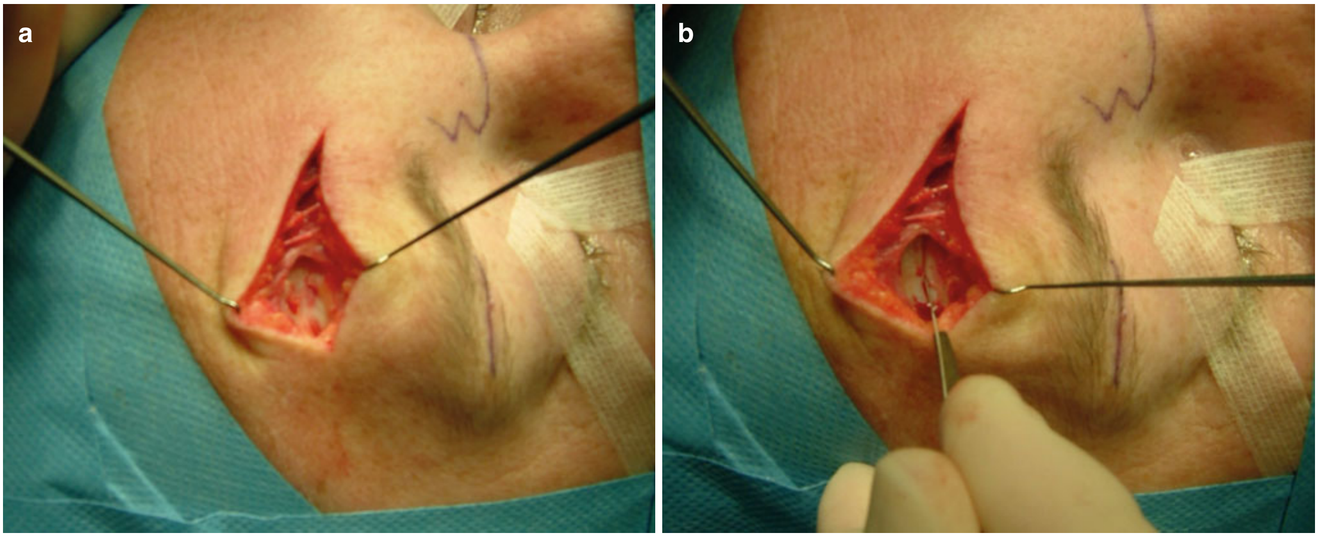

Fig. 16.104 While protecting the nerve, the deeper periosteum was incised (**a**) and elevated (**b**)

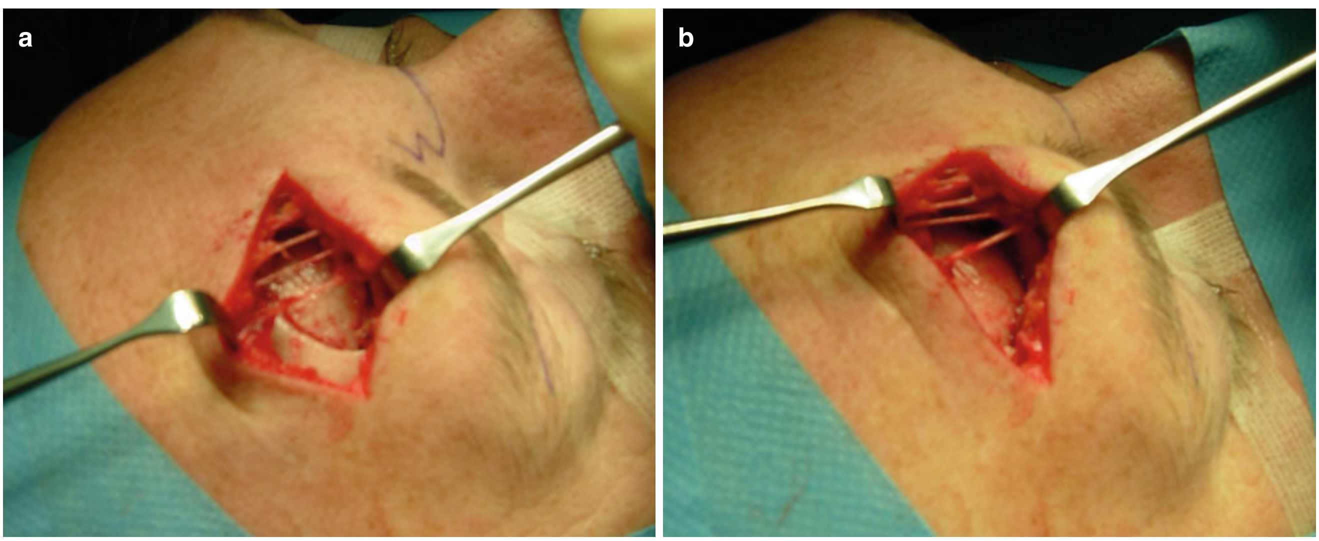

Fig. 16.105 The fracture was carefully defined (**a**, **b**)

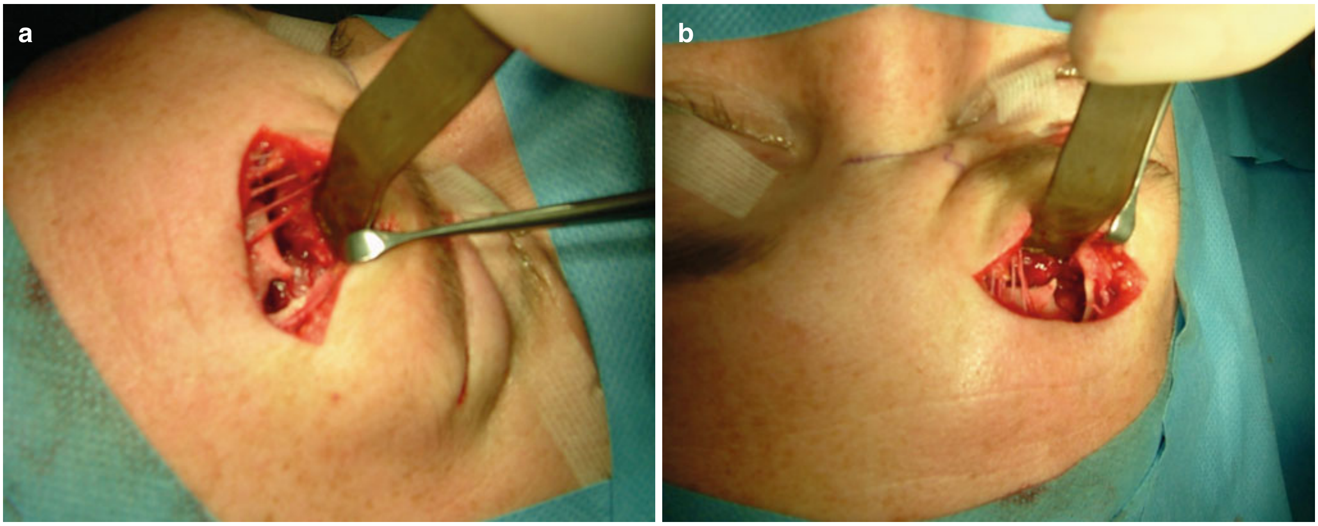

Fig. 16.106 The fracture was significantly depressed (**a**), but isolated to the anterior wall only (**b**)

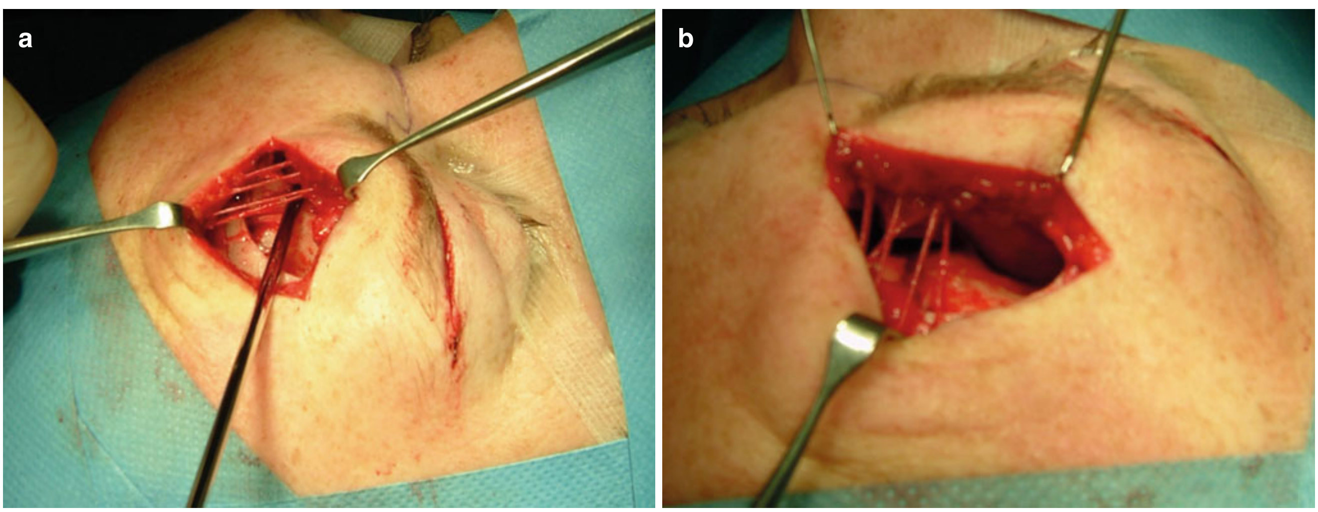

Fig. 16.107 By carefully undermining the periosteum, the fracture can be defined deep to the nerves (**a**, **b**)

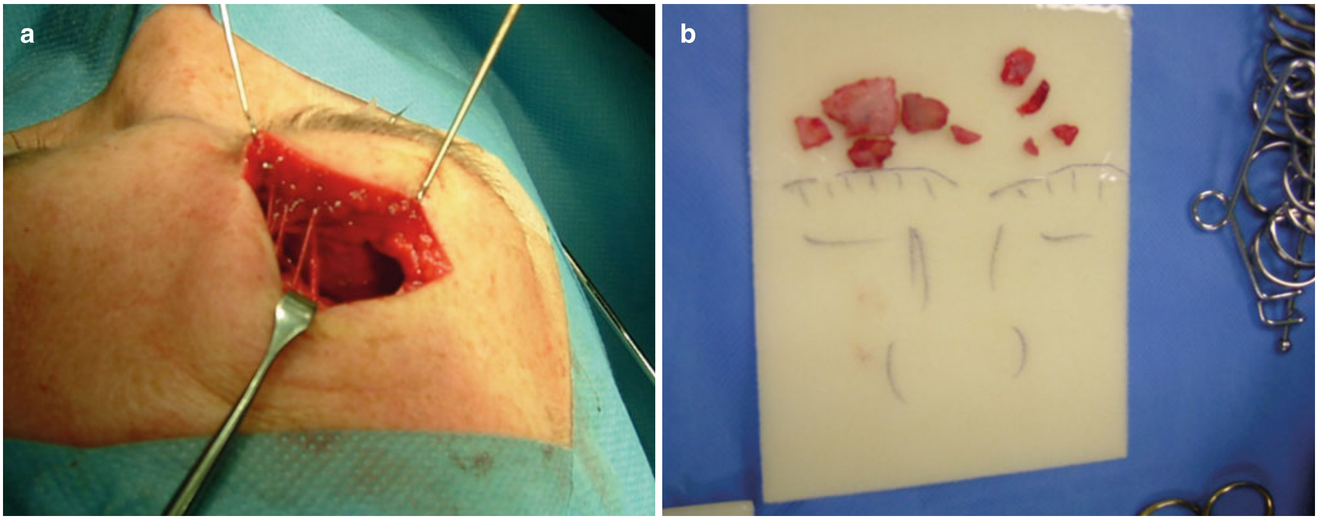

Fig. 16.108 The fragments were carefully elevated (**a**). These were placed on a "sticky-pad" maintaining their spatial arrangements (**b**)

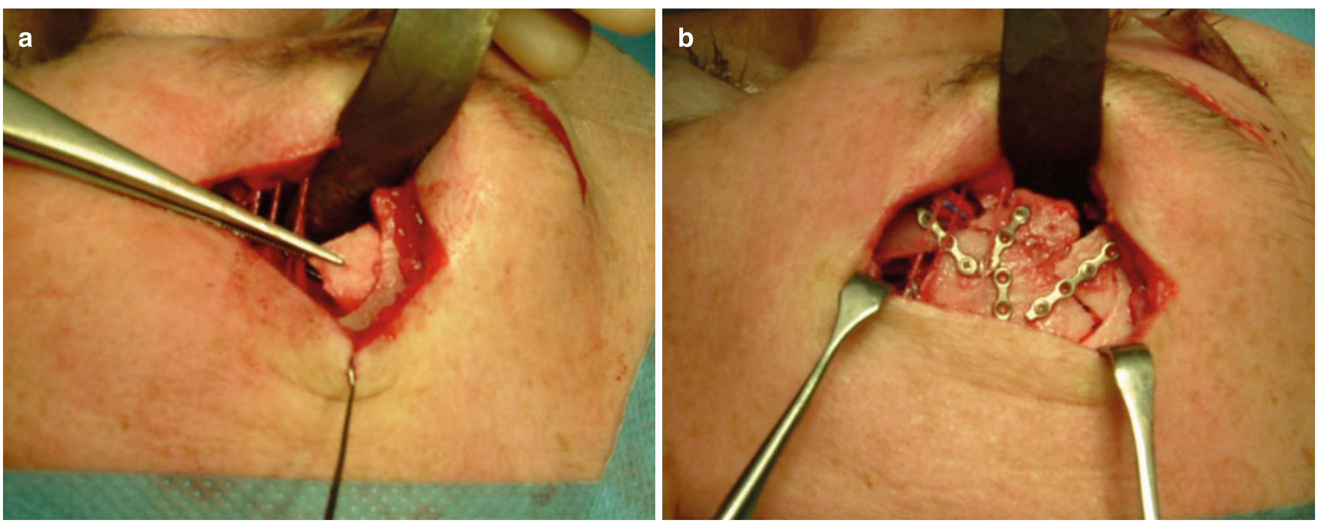

Fig. 16.109 Following inspection of the sinus and frontonasal duct (**a**), the fragments were replaced and repaired (**b**)

Case 3

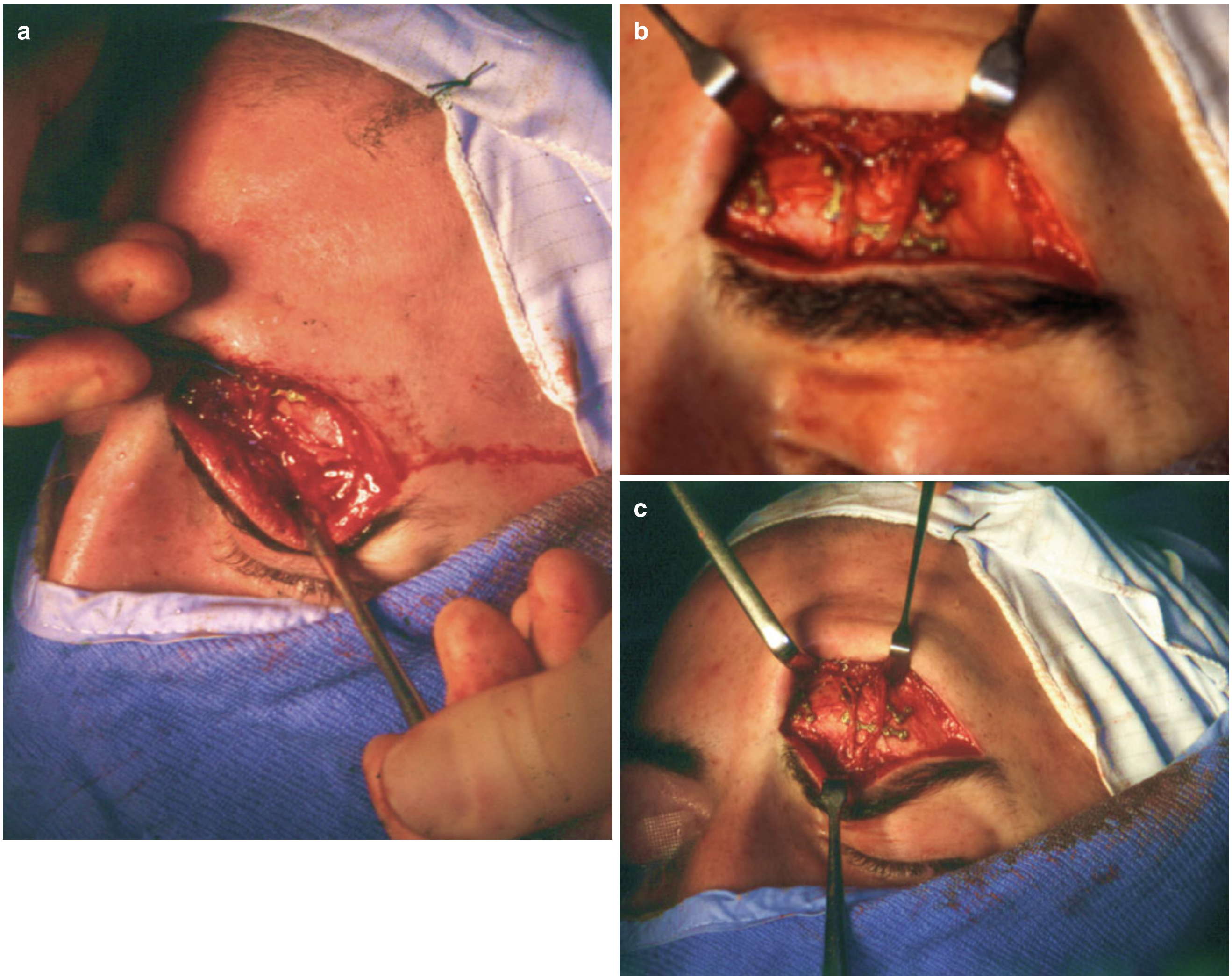

Fig. 16.110 This follows the same sequence as the two previous cases (**a**–**c**)

Repair of frontal sinus fractures is often undertaken using microplates. Short screws are required since the bone is very thin. Screw length selection is important; if the screws are too long, this can result in risks of infection. Invariably some will be but try to keep this to a minimum.

With more extensive fractures, or if there are concerns regarding possible CSF leaks, it is probably safer to raise a coronal flap as shown in the next case.

Case 4

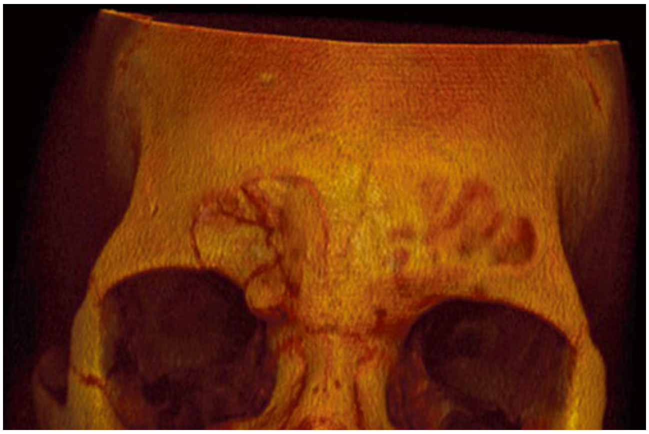

Fig. 16.111 This patient presented following an assault with a crowbar. This produces characteristic injuries—a stellate-type fracture centered over the point of impact. These injuries frequently result in impacted fragments

Fig. 16.112 The coronal incision provided excellent exposure, with the added flexibility to harvest an outer table calvarial bone grafts if required. The pericranial incision can be flexible depending on the need for plate coverage

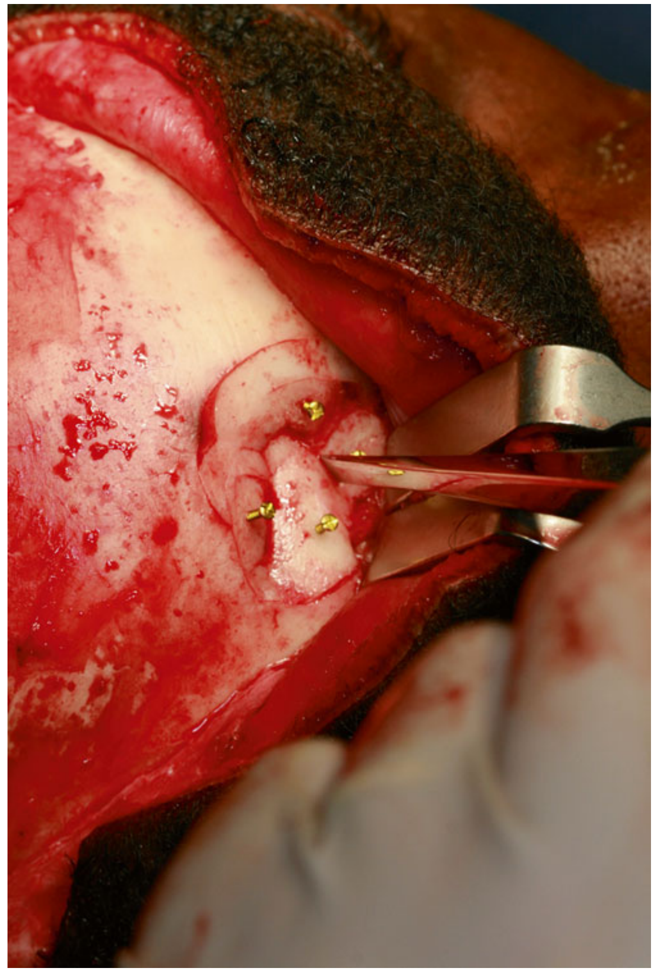

Fig. 16.113 If the fracture is impacted, 1.3-mm positional screws can be placed in the major fragments which are gently mobilised using a 5-mm osteotome. Once engaged this can be gently rotated to help complete any greenstick component to the fracture. Caution must be exercised doing this with very thin bone

Fig. 16.114 Once mobilised the fragments can be gently eased into position

Fig. 16.115 Once the fragments are in position, the reduction can be maintained by 1.3-mm miniplates with 3- or 4-mm screws. It is best to capture at least one larger bone fragment first, before the smaller fragments

Alloplastic Repair of the Anterior Sinus Wall

Occasionally during repair it may become apparent that the fracture has been underestimated or that the bone is too thin and will not support the screws. Management depends on the size, shape, and position of the defect, as well as consent issues (so anticipate this). Options include alloplastic or autogenous graft reconstruction

Autogenous Repair of Anterior Sinus Wall

Bone is often regarded as the "gold standard" in hard tissue reconstruction. Ideally it should be rigidly fixed, but this may not be possible over the sinus. Routine use of bone has now been challenged by the excellent results of titanium alloplast. Nevertheless, if donor bone is available it still has a valid role to play. Sources of bone include:

- Cranial Bone
  - Parietal: outer table
  - Frontal: inner table
- Iliac crest
- Rib
- Opportunistic: rarely following traumatic amputation

The aims of surgery are to reconstruct the anterior table to provide a platform for soft tissue support, whilst providing a safe sinus to prevent medium and long-term infective

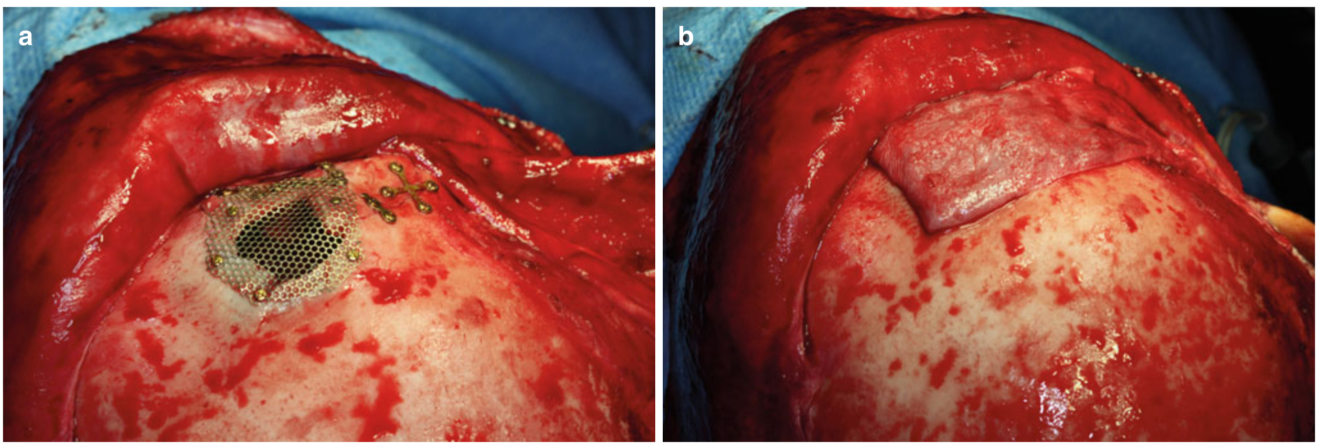

Fig. 16.116 Titanium mesh is suitable for small defects over a flat or mildly curved surface (**a**). This can be covered by a pericranial flap (**b**)

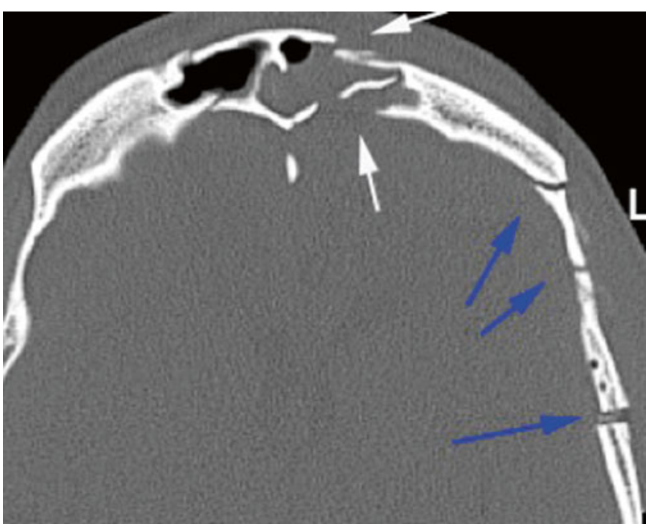

Fig. 16.117 In this case there are a number of fractures to the frontal bone, including fractures to the anterior and posterior tables (*white arrow*) and temporal bone (*blue arrows*). Although the temporal fractures are not displaced their presence is indicative of a high-energy mechanism. Comminution would be expected

Fig. 16.118 Three-dimensional reformatting demonstrates the gross comminution of the nasofrontal region. 3D reformats frequently underestimate the degree of comminution. At the time of surgery the majority of fragments in the defect were very small, and judged unreliable for reconstruction

complications. Treatment planning therefore included the following stages:

1. Craniotomy for anterior and posterior sinus fracture access
2. Cranialisation
3. Calvarial bone graft to reconstruct the anterior wall

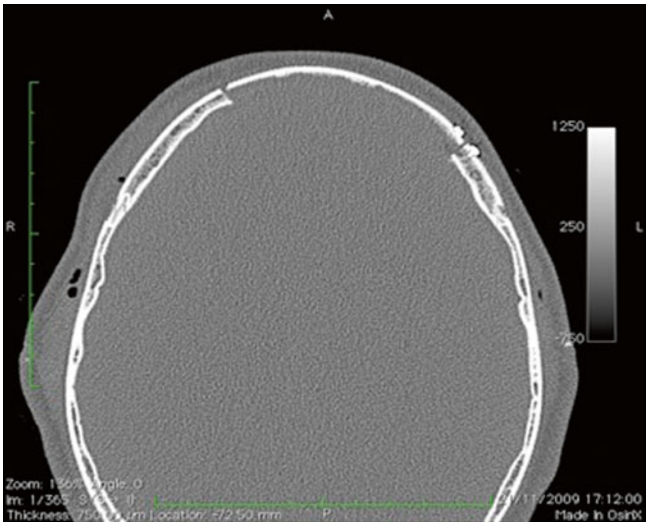

Fig. 16.119 The posterior table can be seen to be missing following removal of the posterior wall of the frontal sinus. The brain and supporting structures seem to have adapted to the new position. This is "formal cranialisation"

Like all bone grafts, the success of cranial grafts is dependent on several things:

1. Adequate immobilization: this allows revascularisation
2. Adequate healthy soft tissue coverage: also required for revascularisation
3. Minimal contamination: to prevent infection. Once infection is established it can be very difficult to eradicate, sometimes necessitating removal of the graft.

Resorption of cranial bone grafts is reported to be minimal, so long as it becomes vascularised. This said, the ability of bone to resorb under a traumatised soft tissue envelope can be an advantage. The bone is then less likely to ulcerate through as the soft tissues contract. It is, however, important to reduce any prominences which place the soft tissues under tension. One problem with cranial bone is the difficulty in conforming it to complex contours. Whilst it may be tempting to osteotomise the bone to facilitate this, a titanium sheet would perhaps be a simpler option.

Reconstruction of Anterior Wall Plus Sinus Obliteration

This may be required following fracture of the anterior table with involvement of the frontonasal duct. A variety of materials have been reported to successfully obliterate the sinus, including abdominal fat, autogenous bone, and pericranium.

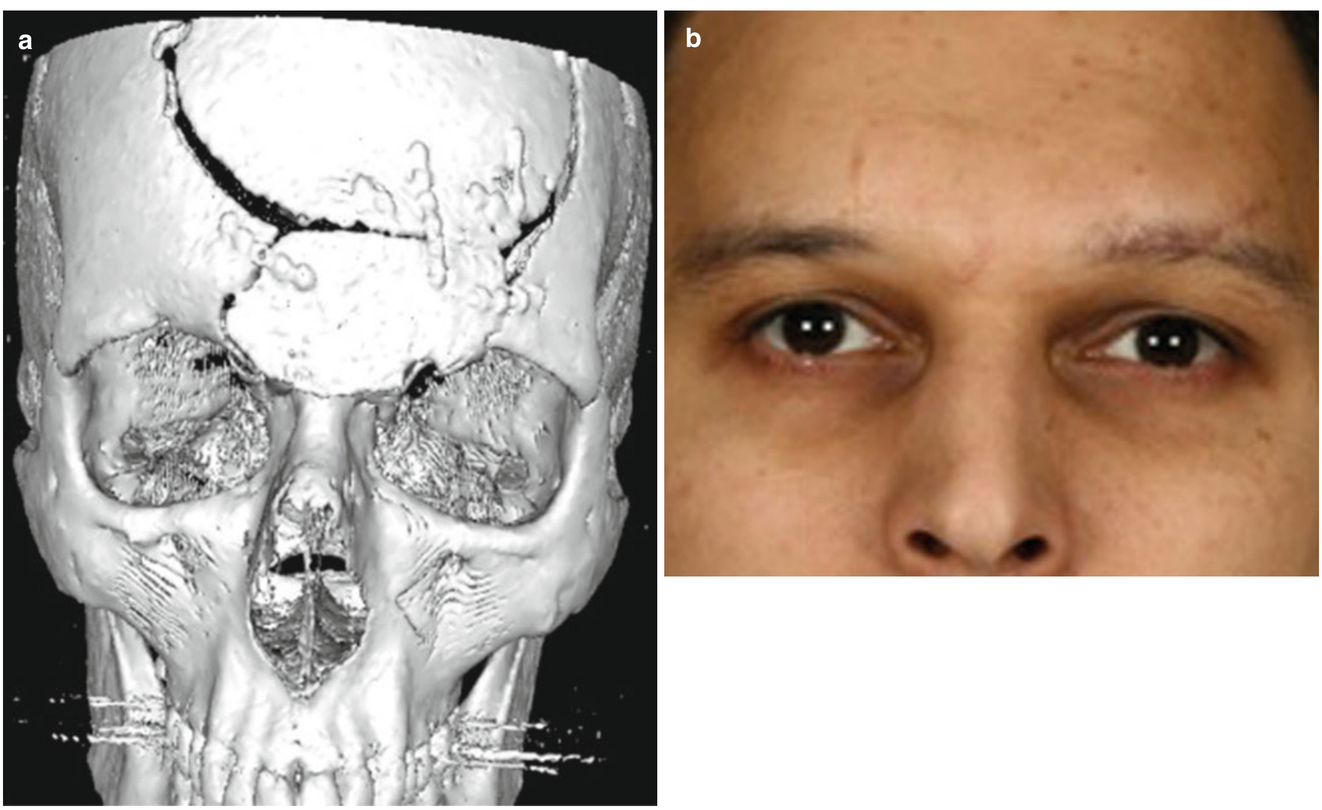

Fig. 16.120 The postoperative 3D reconstruction shows the posterior table graft having been shaped to fit the defect (**a**). One of the advantages of posterior table is the ability to "take a screw" and provide a solid construct. It is also easy to shape and will remodel, smoothing out any irregularities (**b**)

Case 1

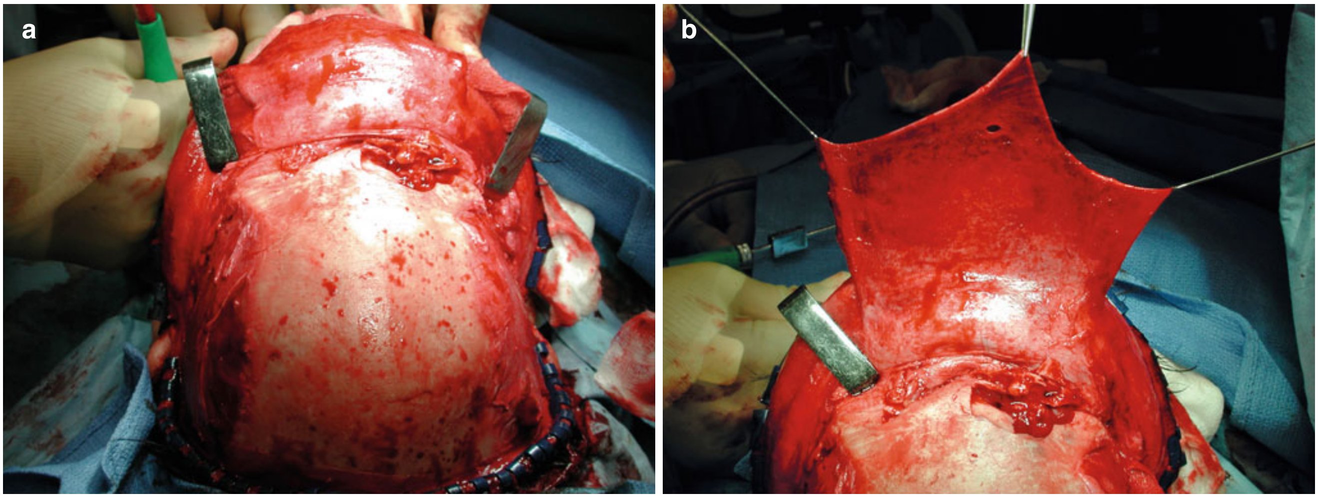

Fig. 16.121 Following raising of a coronal and pericranial flap, the full extent of the anterior table fracture is delineated (**a**, **b**)

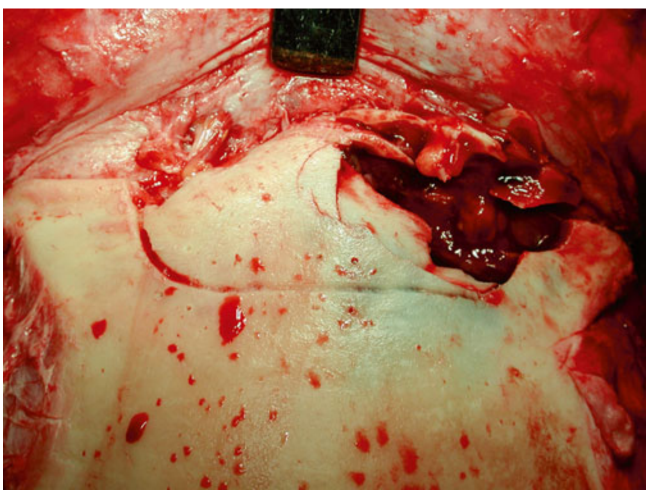

Fig. 16.122 An anterior table osteotomy is marked as shown. Following osteotomy the outer table is removed. The sinus lining is then removed in its entirety. Any loose septal bone fragments are harvested and cleaned. The sinus mucosa around the ostium is inverted into the duct and sealed with a free pericranium graft

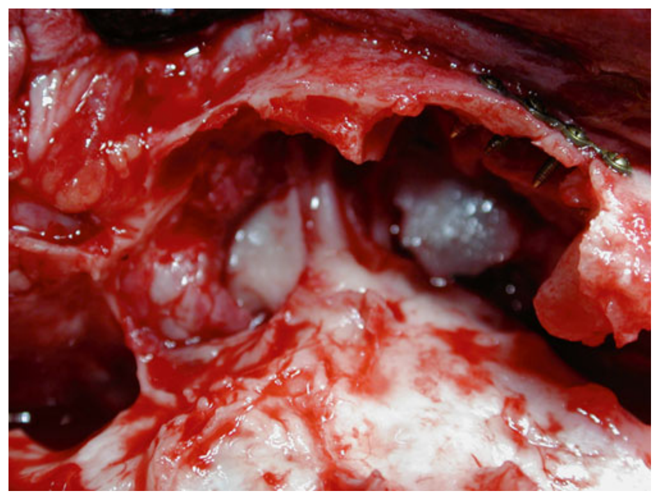

Fig. 16.123 A close-up of the floor of the frontal sinus demonstrating the bone graft in situ at the opening of the frontonasal duct. Fibrin glue is then applied to the area of bone graft

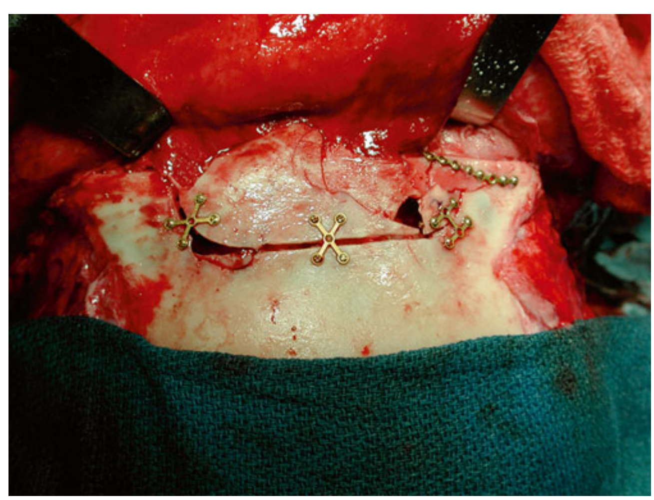

Fig. 16.124 The anterior wall is then reconstructed, and the pericranium inserted via the anterior edge of the repair. The pericranium should totally obturate the cavity; further fibrin glue may also be applied

Posterior Sinus Wall Fractures (Types 2 and 3)

These usually occur with anterior table fractures but can occur associated with NOE fractures, with an intact anterior wall. One area of controversy in the management of these fractures is "how bad" does the fracture have to be in order to justify the risks of "prophylactic" surgery. This is usually considered in a number of ways (Table 16.13).

Posterior table fractures that are displaced more than the width of the bone itself are reported to be an indicator for dural tears and CSF leaks. At the moment of impact, the bone (which is elastic) deforms, resulting in significant, but temporary displacement at the fracture site. This can result in dural tears even though the fractures do not seem to be too displaced on CT (by way of analogy, during an earth tremor, wallpaper [the dura] may tear as a brick wall [the bone] momentarily moves, but then returns to a closer resting position). It is also argued that sinus mucosa may become trapped between the fracture edges, preventing healing and leading to a persistent communication. If the frontonasal duct is partially obstructed, mucocele formation is also a possibility.

Management of posterior frontal sinus wall fractures therefore depends on the perceived risks of meningitis. When dural tears are evident, the options are therefore to:

1. Either proceed to a craniotomy with formal repair of the dura and cranialise the sinus or
2. To adopt a "wait and see" approach—most CSF leaks will spontaneously cease if left alone.

Craniotomy and dural repair is a major surgical procedure, with potentially significant complications. Some surgeons therefore argue that in the absence of an active CSF leak, this is not justified on the basis that the patient *might* get meningitis; i.e., this is a major "prophylactive" procedure. However, others argue that since the risks are lifelong, the cumulative risk becomes high and can justify surgery. This remains an area of ongoing controversy. One interesting perspective is "if you had this injury, what would you have done?"

When obstruction of the frontonasal duct is present, there are three treatment options: restore the anatomy, cranialise the sinus, or obliterate it. Attempts at repairing the frontonasal duct using stents have been reported. However, stenosis is a problem in approximately one third of patients. The principle behind cranialisation is to remove the posterior sinus wall, remove all mucus secreting epithelium from the remaining cavity, plug the frontonasal ducts, and allow the brain to expand into the cavity. Obliteration involves removing all of the mucosa from the frontal sinus, filling the sinus with autogenous material such as fat or pericranium, and plugging the frontonasal duct with fat, to essentially isolate the frontal sinus from the nose.

Wide access to the frontal sinus requires a coronal flap. Previously used approaches included the "Gullswing" incision placed just above the eyebrows. Depending on the fracture configuration of the anterior wall, access to the posterior wall and frontonasal duct may vary. Where there are extensive mobile fragments, these may be gently lifted out and kept safe. If this is not possible, fenestration of the anterior wall is possible, being careful not to stray beyond the margins of the sinus. In some cases, a craniotomy will be required to provide adequate access for dural repair.

The decision to operate and exactly what to do is therefore controversial. This depends on displacement of the posterior wall, which is classified as positive if the separation is greater than the thickness of the posterior sinus wall. Other indications include persistent CSF leak, or the presence of intracranial air. One treatment algorithm is shown, but others exist.

Table 16.13 Determining treatment need in posterior frontal sinus fractures

Consider the following
Is a craniotomy required for some other reason?
Is there ongoing/persistent CSF leak?
Is there significant intracranial air?
Is there evidence of frontonasal duct obstruction?
Are there any associated craniofacial fractures requiring repair? How displaced is the posterior wall fracture?

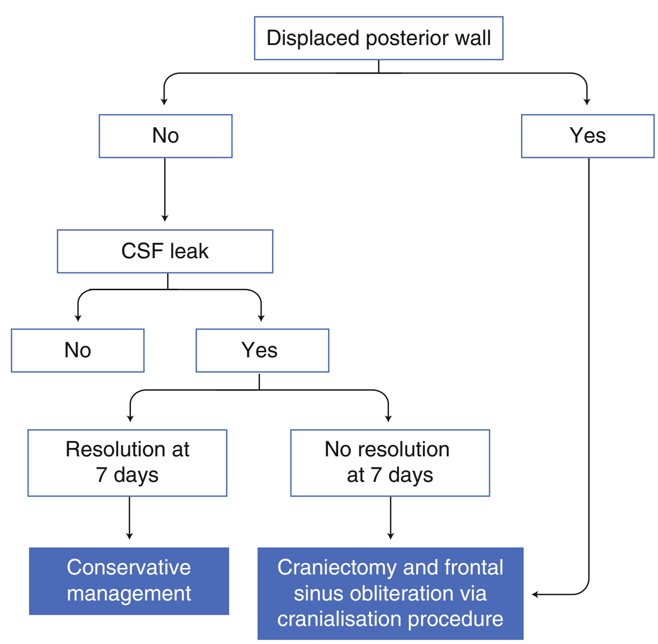

Fig. 16.125 Management of types 2 and 3 sinus fractures (posterior wall)

Cranialisation of the Posterior Frontal Sinus Wall

Case 1

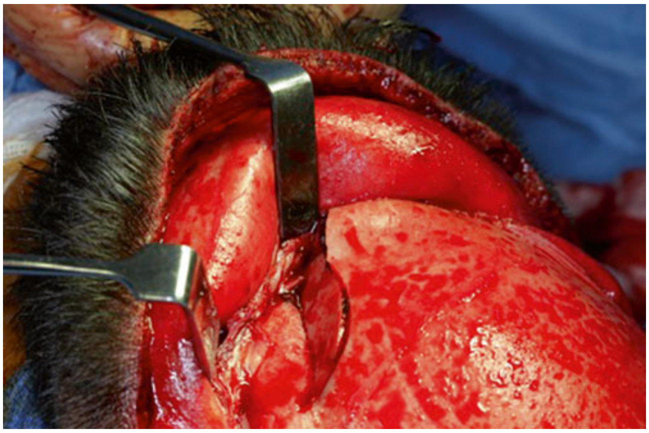

Fig. 16.126 This case of a combined anterior and posterior frontal fracture demonstrates the technique of cranialisation. Following craniotomy, haemostasis, brain retraction, and removal of sinus lining, the posterior wall is carefully removed by rongeurs

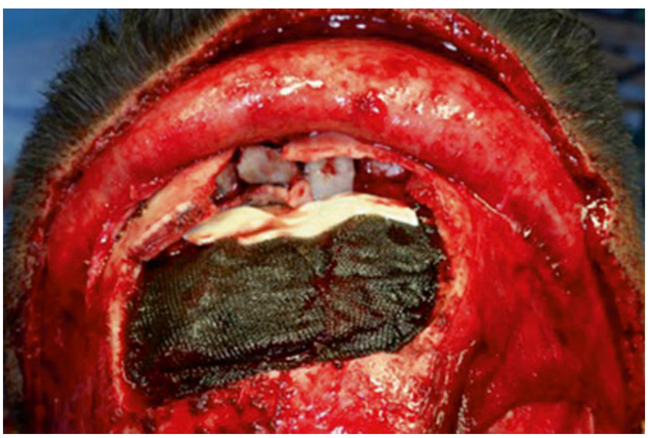

Fig. 16.127 The cavity is obturated in a layered fashion. This includes free pericranium, fibrin glue, free bone graft, more fibrin glue and lastly, pedicled pericranium. The bone graft is taken from the fragmented posterior wall after it has been stripped of mucosa. This supports the pedicled pericranium

Fig. 16.128 The pedicled pericranium is based laterally on the right side and layered on top of the bone graft

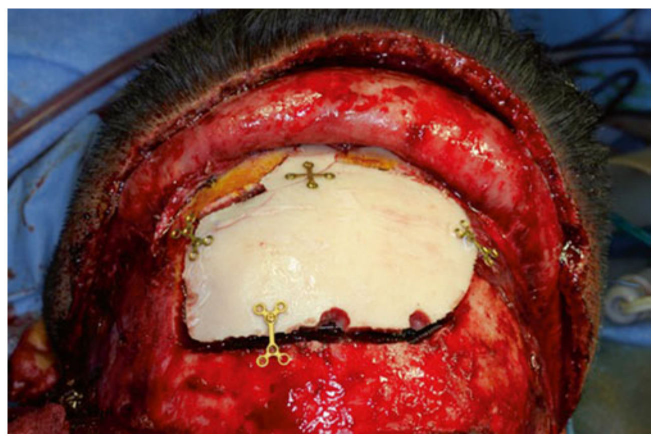

Fig. 16.129 The bone flap is then returned

Case 2

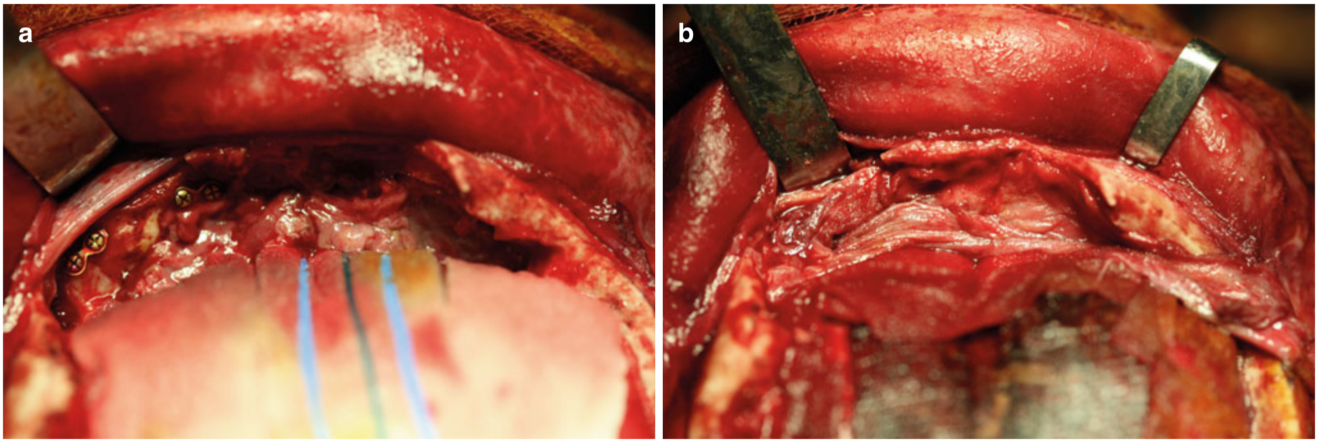

Fig. 16.130 In this case the frontal sinus has been cranialised. There are extensive fractures involving the skull base and orbital roof. The pericranium therefore not only supports the sealing of the skull base, but also supports the repair (**a**, **b**)

Anterior Table Fenestration (Osteotomy)

Case 1

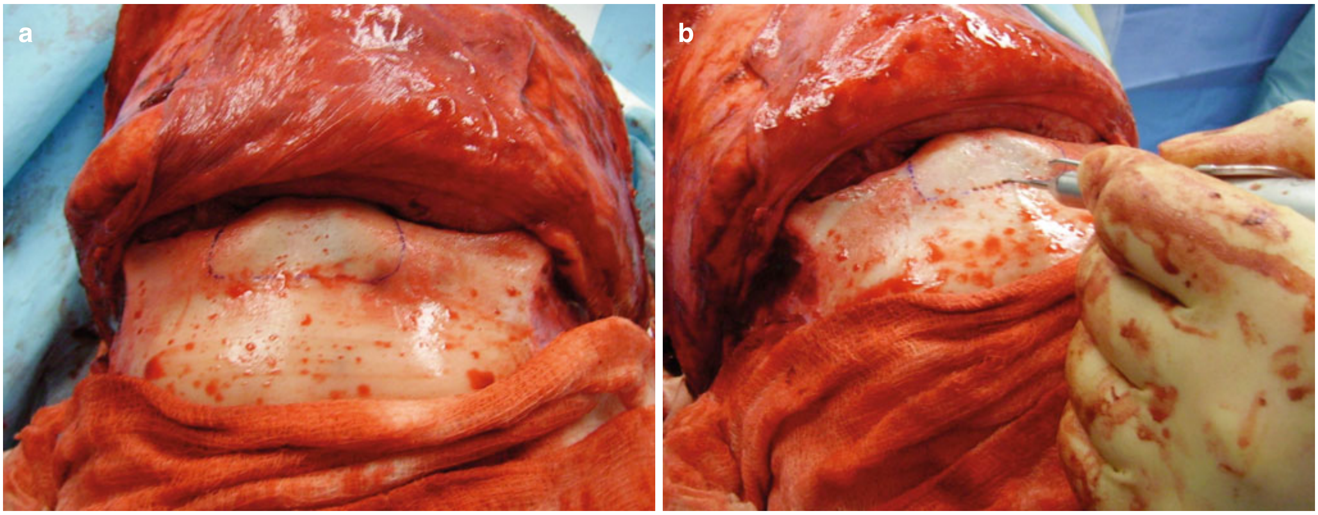

Fig. 16.131 In this case the patient had displaced nasoethmoid fractures and a few "cracks" in the posterior fontal sinus wall. There was an inconclusive history of CSF leakage. Since these fragments were all interconnected, any manipulation of the NOE complex could displace the posterior wall fragments and tear dura. It was therefore decided to manipulate the NOE complex while directly inspecting the posterior wall. The sinus was carefully mapped out using the CT images. A "postage stamp" technique ensured precise placement of the bone cuts (**a**, **b**)

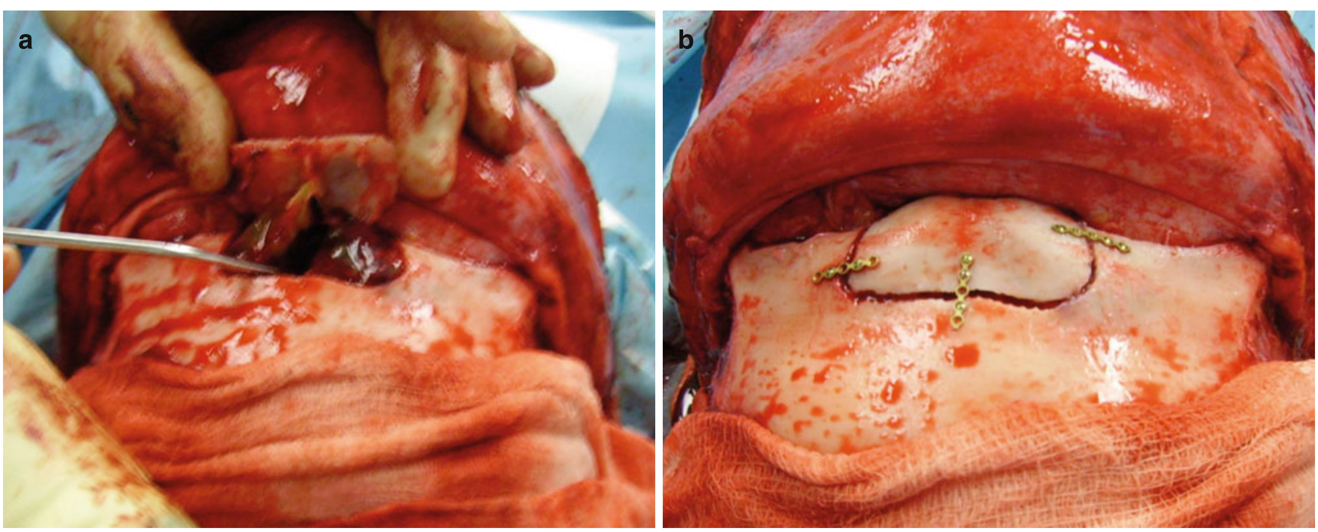

Fig. 16.132 The anterior wall was elevated (**a**). In this case both the posterior sinus wall and frontonasal ducts were clearly intact following NOE manipulation. There was therefore no indication to cranialise or obturate the sinus and the anterior wall was repositioned and plated (**b**)

Case 2

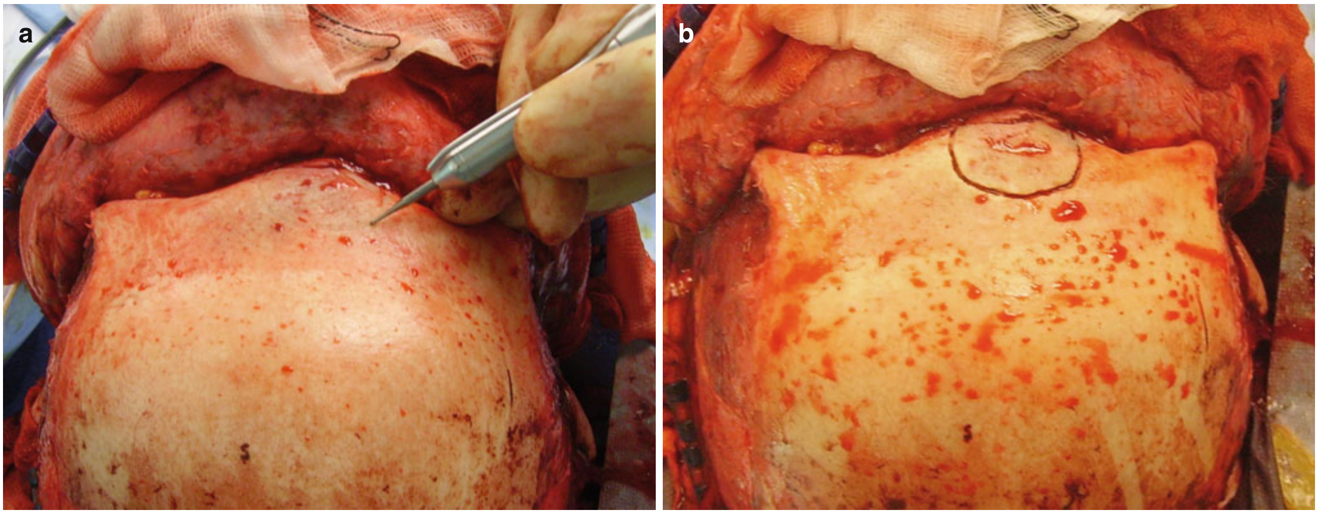

Fig. 16.133 In this case the frontal sinus was relatively small and therefore a small window was cut (**a**, **b**)

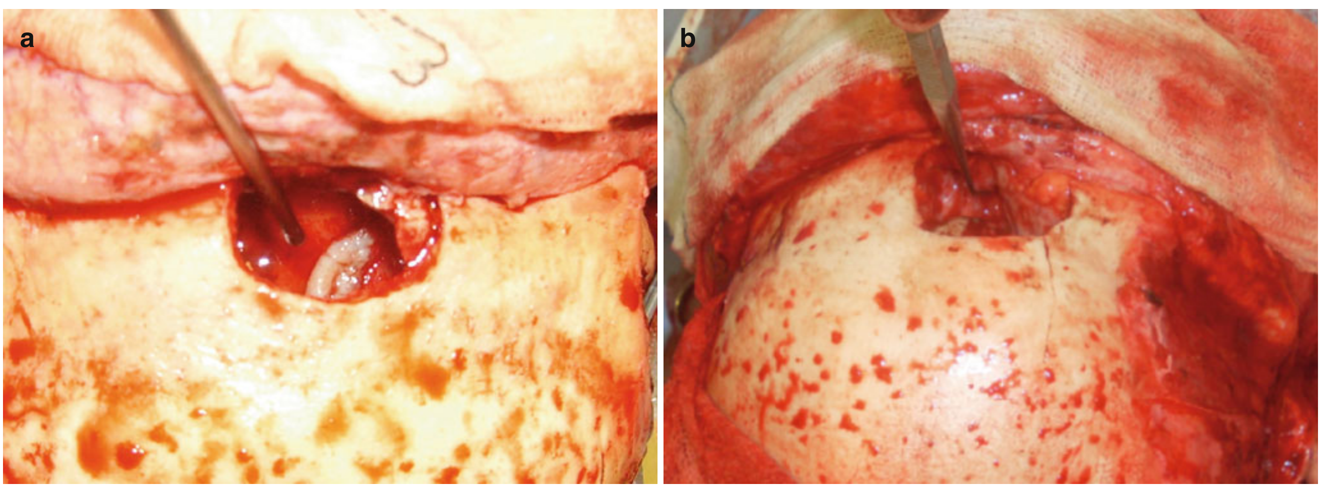

Fig. 16.134 On removing the bone, CSF was seen within the sinus (**a**). The frontonasal duct was not clearly defined due to mobile bone fragments and mucosal swelling (**b**)

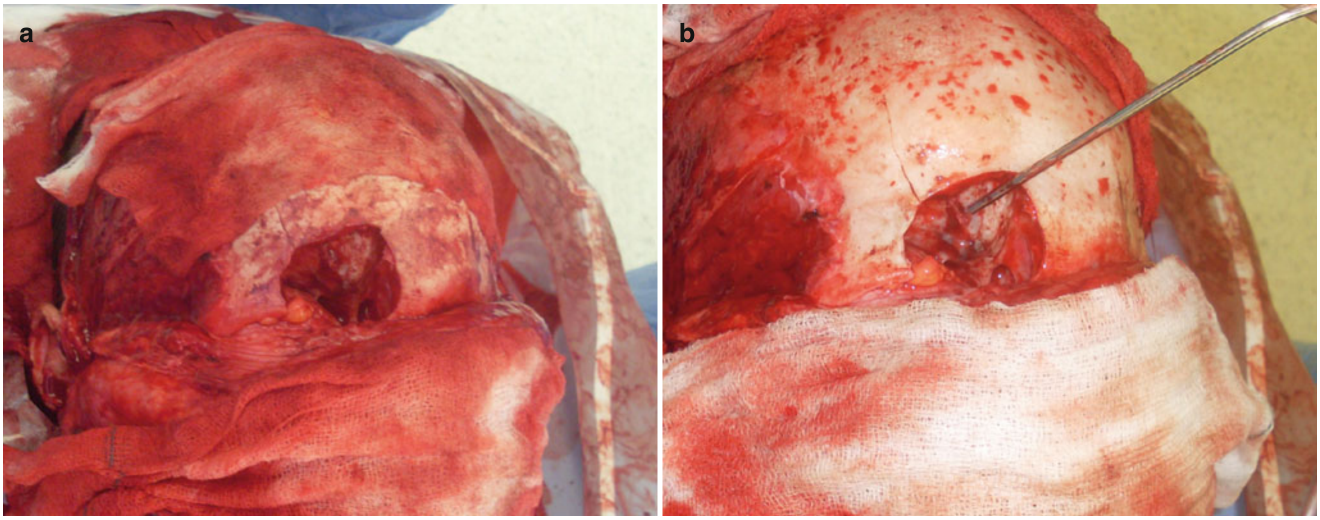

Fig. 16.135 The mucosa was carefully stripped to reveal multiple small cracks along the posterior wall (indicated by the suction cannula) (**a**). There was no displacement (**b**)

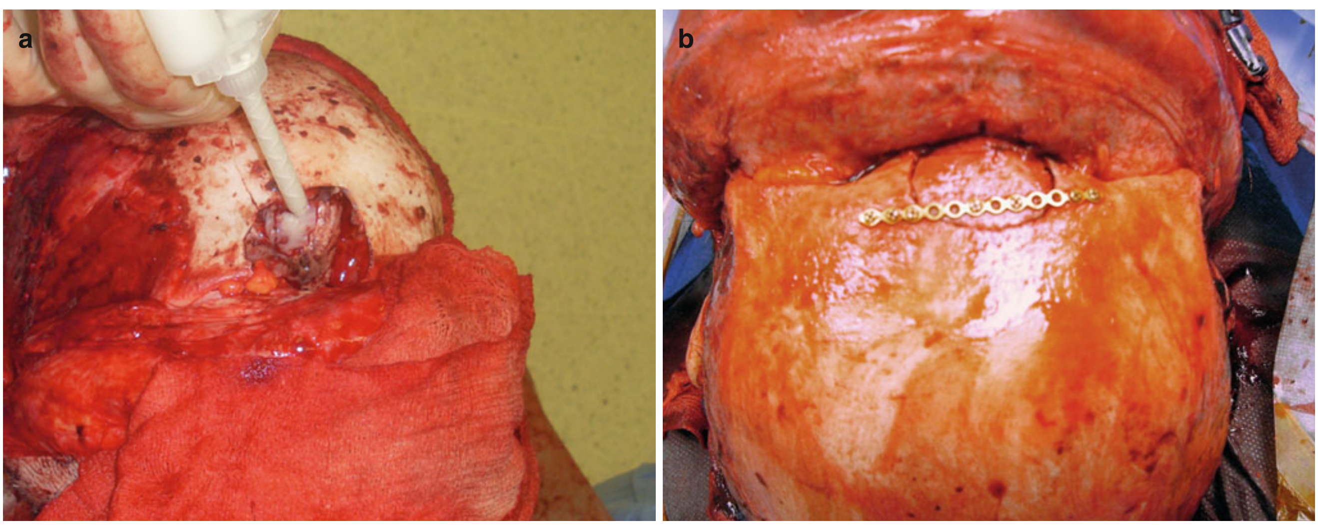

Fig. 16.136 In this case it had been decided preoperatively that cranialisation was not indicated. Sinus obliteration was performed instead. The mucosa was stripped away and the sinus obliterated first with bone chips and Tisseal placed at the duct, followed by Tisseal along the posterior wall and a pericranial flap to fill the small cavity (**a**). The anterior wall was then replaced (**b**)

16.11.2.2 Complex Through-and-Through Defects with Associated Soft Tissue Trauma (Type 4)

With continued improvements in the management of severe trauma, patients who would have otherwise died from their injuries are now surviving. Consequently, these complex sinus injuries are now being presented for treatment more frequently. Such patients present significant and complex problems that have to be managed on a case-by-case basis. This is illustrated in the following cases.

Case 1

This patient was a cyclist who cycled into a telegraph pole.

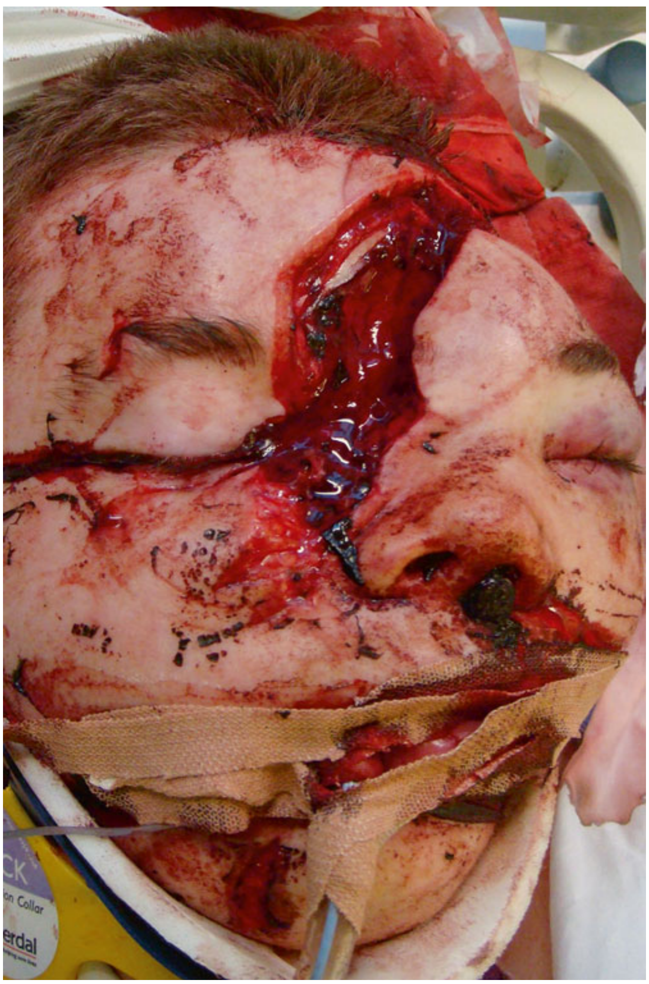

Fig. 16.137 In these complex cases, ideal treatment may need modification. For example, fixing the fractures through a wound such as this case would be straightforward, but how is the anterior skull base to be sealed? How would it be best to reconstruct the defect, given that in this case cranial bone cannot be used? In other cases with traumatic forehead wounds, coronal access may be good for the cranial aspect, but will the incision devitalize the forehead flap?

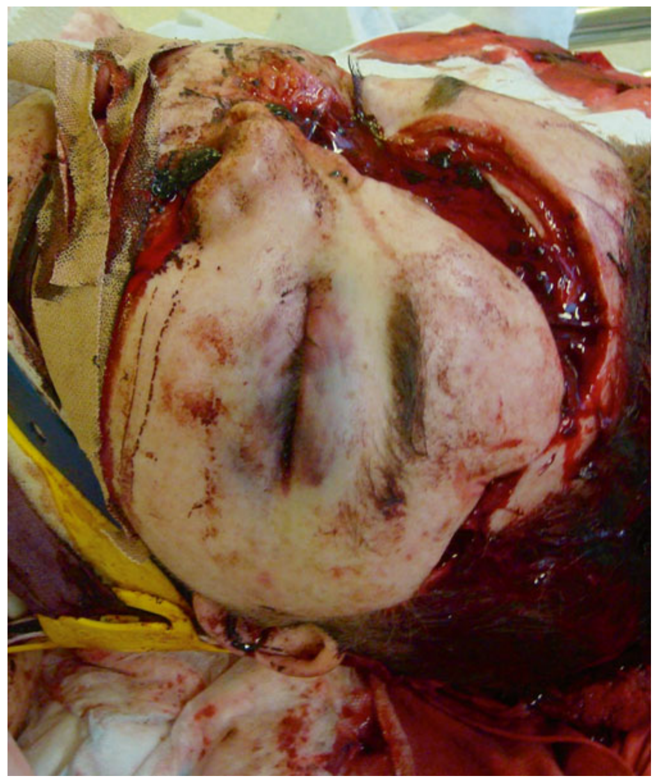

Fig. 16.138 Correct evaluation and management of the soft tissue component is extremely important to successful repair. In addition to the laceration and ruptured left globe the second, third, fourth, upper divisions of the fifth, and the sixth were completely avulsed through the cavernous sinus

Fig. 16.139 The 3D reconstruction demonstrates the magnitude of the injury with extensive comminution of the frontal sinus, entire left orbit and contiguous structures. There was also a Le Fort I fracture with a split maxilla and disarticulated NOE complex. Such fractures are commonly associated with extensive soft tissue damage (through crushing of the tissues as well as laceration)

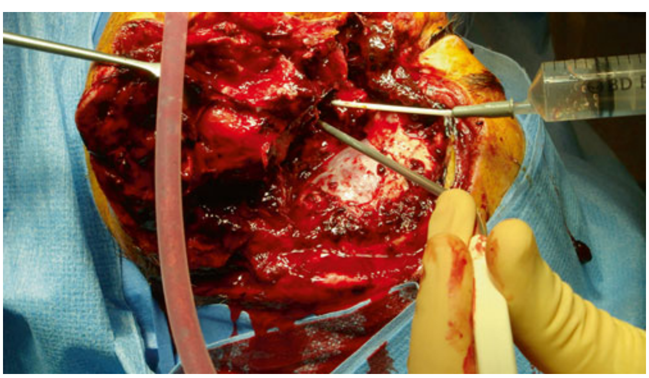

Fig. 16.140 The entire orbit and frontal bandeau were mobilised forward to show the dura mater. Haemorrhage was controlled with Surgicel, bipolar and bone wax

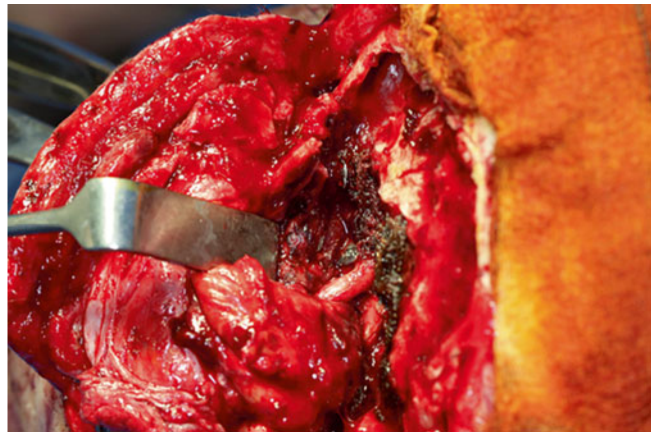

Fig. 16.141 This view shows the severed left optic nerve alongside the tip of the Howarth's periosteal elevator, which had been passed through the nose. Surgicel was placed on the cavernous sinus. This represents extensive injuries to the anterior cranial fossa (and beyond)

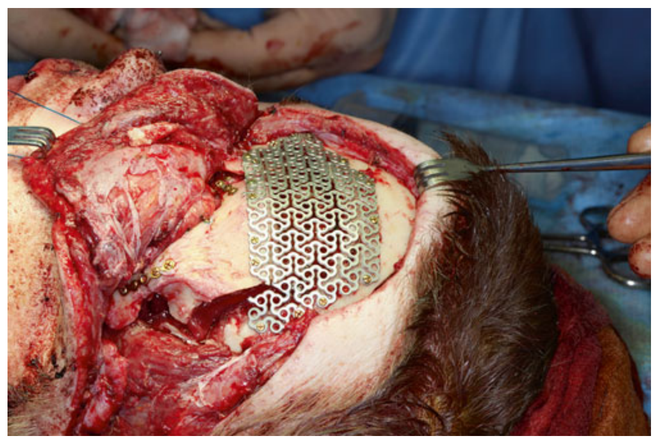

Fig. 16.142 Titanium was used to reconstruct the sinus following cranialisation. This also helped to anchor all the remaining fragments in the correct 3D position. Note the mobilisation of temporalis inferiorly, allowing an area of cross referencing to help establish the vault position

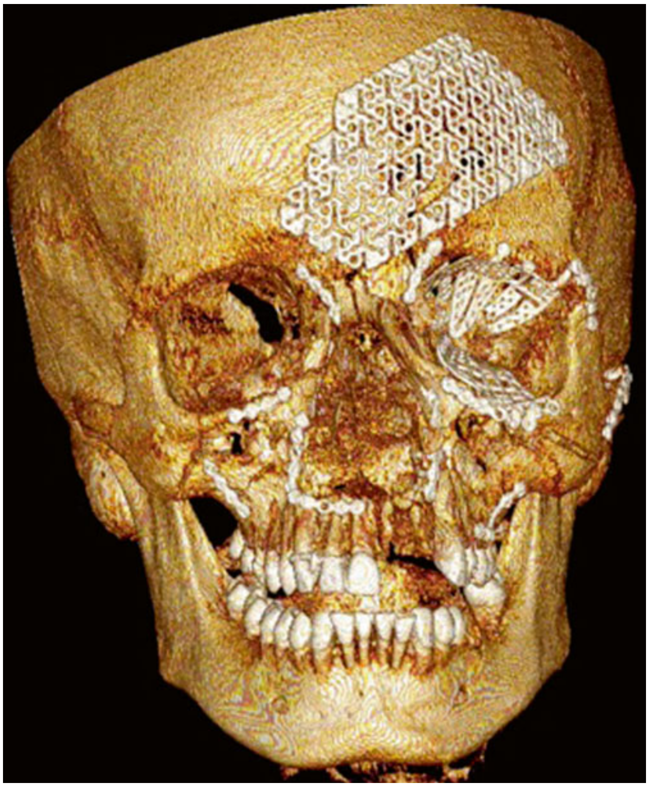

Fig. 16.143 The final reconstruction is seen here. Note the approximation of the upper roof plate to the lower one. This was an attempt to seal off the cranial fossae from the orbit and to reduce the orbital volume to facilitate secondary reconstruction of the contracted globe

Case 2

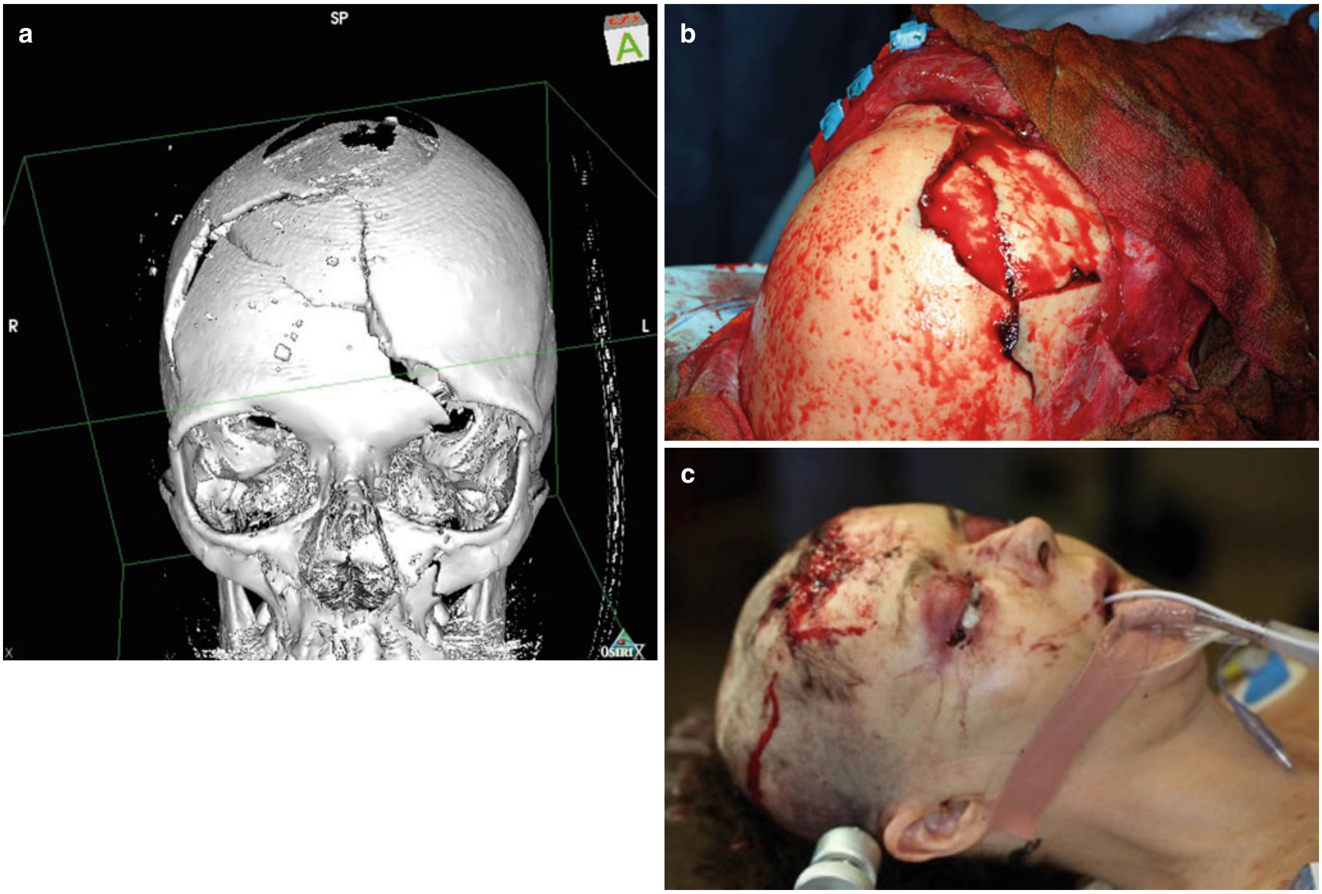

Fig. 16.144 In this case the extent of the vault and anterior skull base fractures totally preclude the use of an extended local incision. The patient required elevation of the frontal bone plus evacuation of haematoma

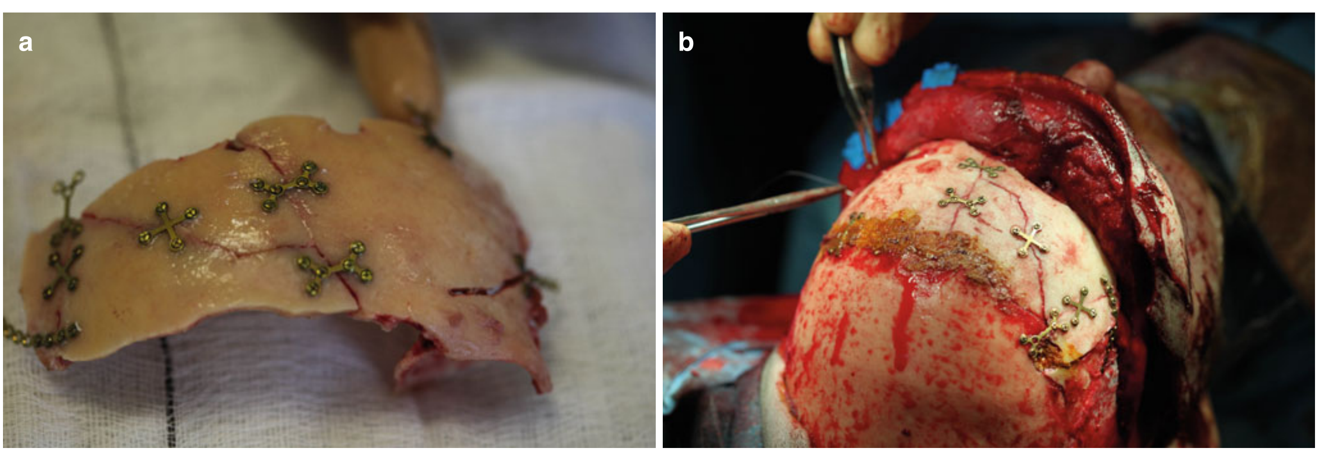

Fig. 16.145 The complex bone fracture was repaired extracorporally. This was then fixed in situ following cranialisation of the frontal sinuses. The bone flap was plated and bone slurry placed on the articulations. A large laterally based pericranial flap provided good cranial base covering. Further pericranium was placed under the soft tissue defect which required secondary grafting

Fig. 16.146 Postoperative appearances

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“Is This Right?”: On-Table Assessment of Our Repair

17

Michael Perry

Every operation has a beginning and an end, and at some point we have to ask ourselves “is this right? Can I now start to close?” Although precise anatomical repair of an injury is often self-evident, this may not be easily determined in every case. Furthermore, not every fracture may need to be fully exposed. The entire fracture pattern of a zygoma, for instance, is rarely exposed along its entire length. So what else can we use to guide us?

Anatomical reduction of fractures is, of course, the aim of repair. But in its strictest sense, achieving a true anatomical reduction with absolutely precise restoration of bony contour can be surprisingly difficult. This is due to the natural malleability of bone. Bone is a “plastic” material and as such undergoes a degree of deformation following impact, before it finally fractures. This is particularly noticeable in thin bone, children (greenstick fractures are an illustration of this), and also following high-energy impacts. Each fragment in a comminuted fracture may therefore have undergone a small degree of deformation. Although this may be minor, when all these are added together the final deformation may be quite obvious. Consequently, in the more widespread fractures, precise anatomical reduction of all the fragments and accurate restoration of pre-injury bony contour can sometimes be somewhat disappointing. Although each fracture by itself appears well reduced, minor discrepancies can add up, resulting in a larger discrepancy elsewhere. This is particularly noticeable in the frontal sinus where, due to the thinness of the bone, a minor degree of deformity is common.

Repairing extensive or comminuted fractures is therefore not just simply a case of putting all the pieces of the “jigsaw puzzle” back together. Just like Humpty Dumpty, putting patients precisely “together again” may not be possible. A degree of judgement is therefore often required in deciding whether the final result is acceptable or not. Although operative imaging (ultrasound, computed tomography [CT], endoscopy and navigation) has been reported to be advantageous, this is not widely available and cannot be applied in every case.

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Similarly with soft tissue injuries, swelling, ischaemia, necrosis and irregularity of the tissue edges can make precise anatomical repair virtually impossible and clinical judgement is again required in deciding whether the repair is "right" or not.

Nevertheless, despite these shortcomings, satisfactory (or better) outcomes are still possible if attention is paid to a number of key sites in the repair process. Whereas minor irregularities in the occlusion, maxillary wall, or along the lower mandibular border may be barely perceptible to the patient (or surgeon), medial canthal drift of more than a few millimetres is likely to result in a very obvious deformity.

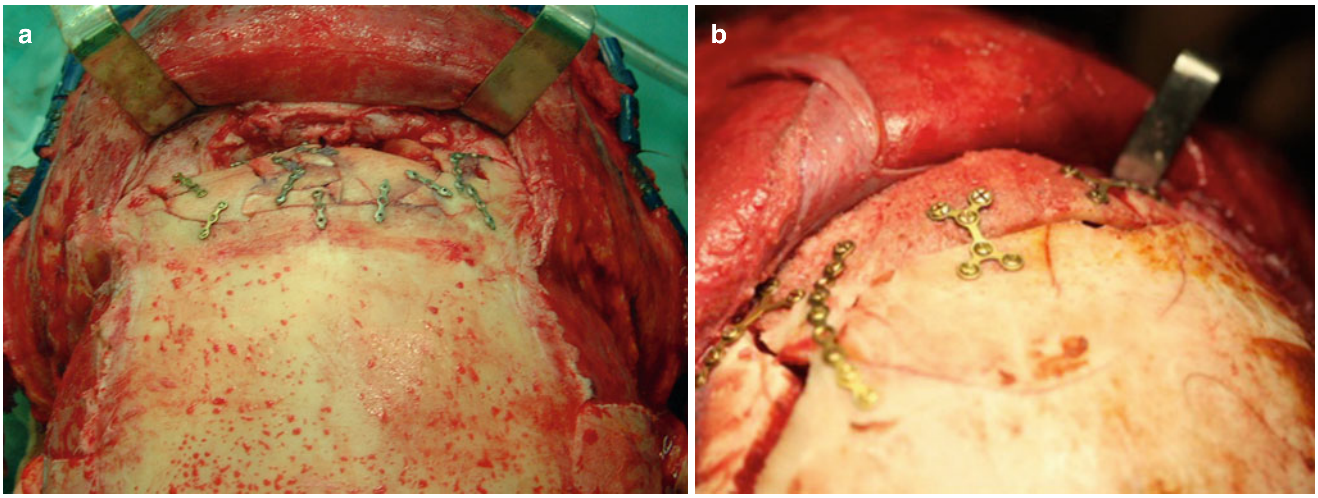

Fig. 17.1 Minor inaccuracies in the repair of comminuted fractures is very common. Although the final result is not a true "anatomical" repair, it is nevertheless acceptable (**a**, **b**)

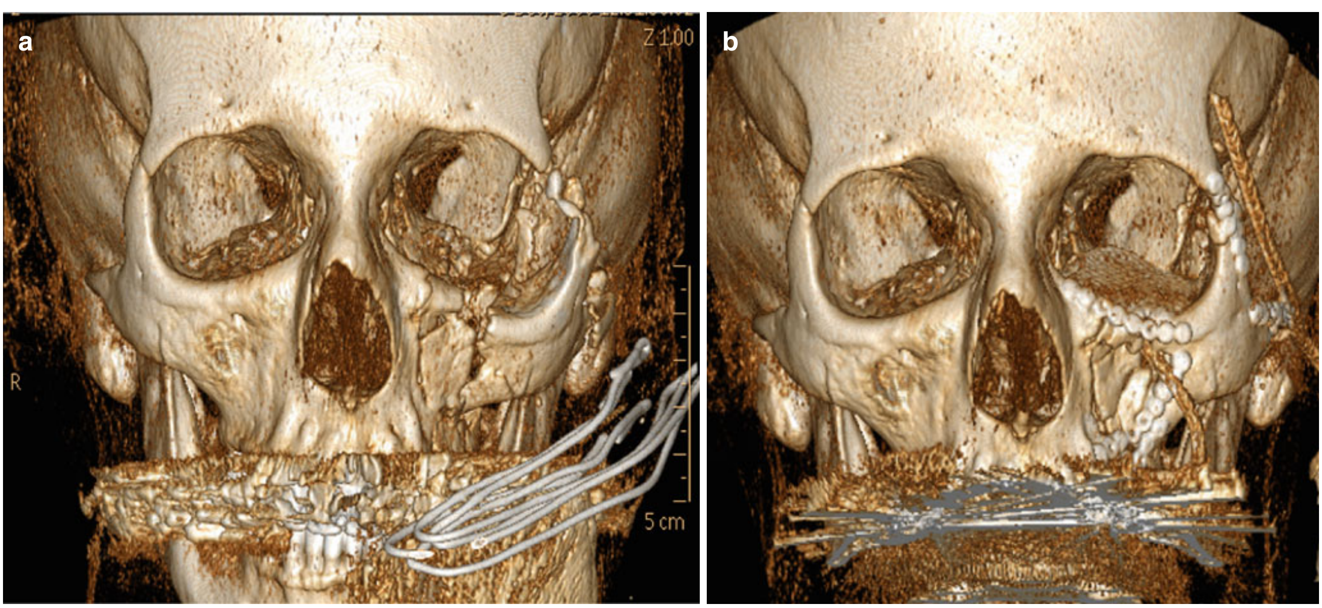

Fig. 17.2 A satisfactory repair. Even though some fragments are not anatomically reduced (on the anterior maxilla), the "key" sites appear to be (infraorbital rim, zygomaticofrontal [FZ] suture and lateral orbital wall) (**a**, **b**)

Prior to wound closure and during the finishing processes of repair it is therefore useful to have a "checklist" of these key sites and areas. Such a list is suggested in Table 17.1. This list may also be useful during the treatment-planning stage. Which of these sites are important in any particular patient will of course depend on the fracture pattern.

It is important to remember that successful treatment is not just about getting things back together again. It also includes making sure function is restored and there are no complications. Aftercare plays an important part in this.

Table 17.1 "Have I repaired this well?"

Consider the following
Do the fractures appear to be anatomically reduced?
Check zygomatic arch alignment, cheek projection and transverse facial width.
There should be minimal bowing of the arch.
Check the lateral orbital wall. Is there correct orientation and alignment of the sphenozygomatic suture?
Check orbital floor plate orientation and its alignment with the posterior ledge.
Check pupillary levels and divergences.
Is there any enophthalmos or proptosis? Minor degrees of proptosis following orbital repair may be reassuring (you would expect some swelling to be present).
Do a forced duction test.
Check intercanthal distance and symmetry. Ideally this should be measured and compared to preinjury photographs of the patient.
Check for CSF leakage. Lightly pack the nose with dry ribbon gauze for a few minutes, then withdraw and inspect.
Has the nasal septum been aligned and supported adequately?
Has nasal projection been restored and does the nose appear straight?
Check the occlusion/midlines and mouth opening.
Is bone grafting required?
Does the patient require postoperative hooks/arch bars and IMF?
Have the soft tissues been resuspended?
Are drains required?
Is there adequate soft tissue coverage over the metalwork? (this is particularly important where plates could be palpable)

17.1 Do the Fractures Appear to Be Anatomically Reduced?

Although this is what we aspire to, precise anatomical reduction is often difficult. If this level of precision was possible, all repaired fractures would appear as fine cracks both on the operating table and on postoperative radiographs.

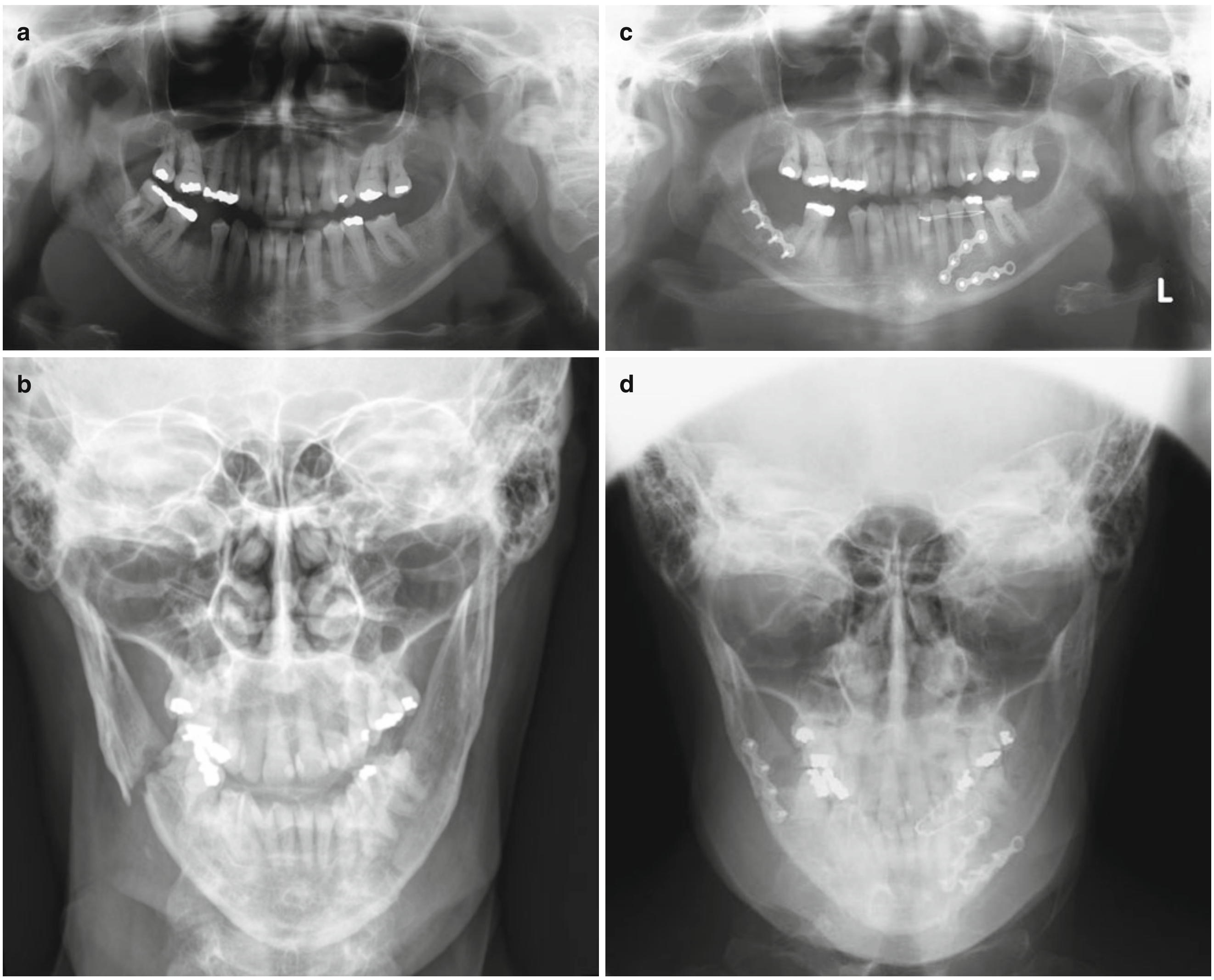

Fig. 17.3 A rare example of "anatomical" repair. The fractures appear as "cracks" following reduction (**a**–**d**)

However, minor discrepancies can often be accepted. What is acceptable depends on the anatomical site and overlying soft tissues. Minor steps in the reduction (and the plates themselves) are more likely to be palpable where the soft tissues are thin (e.g., infraorbital rim), compared to where they are thick (e.g., under a coronal flap). It is therefore important to feel the underlying repair through the repositioned soft tissues as part of this assessment.

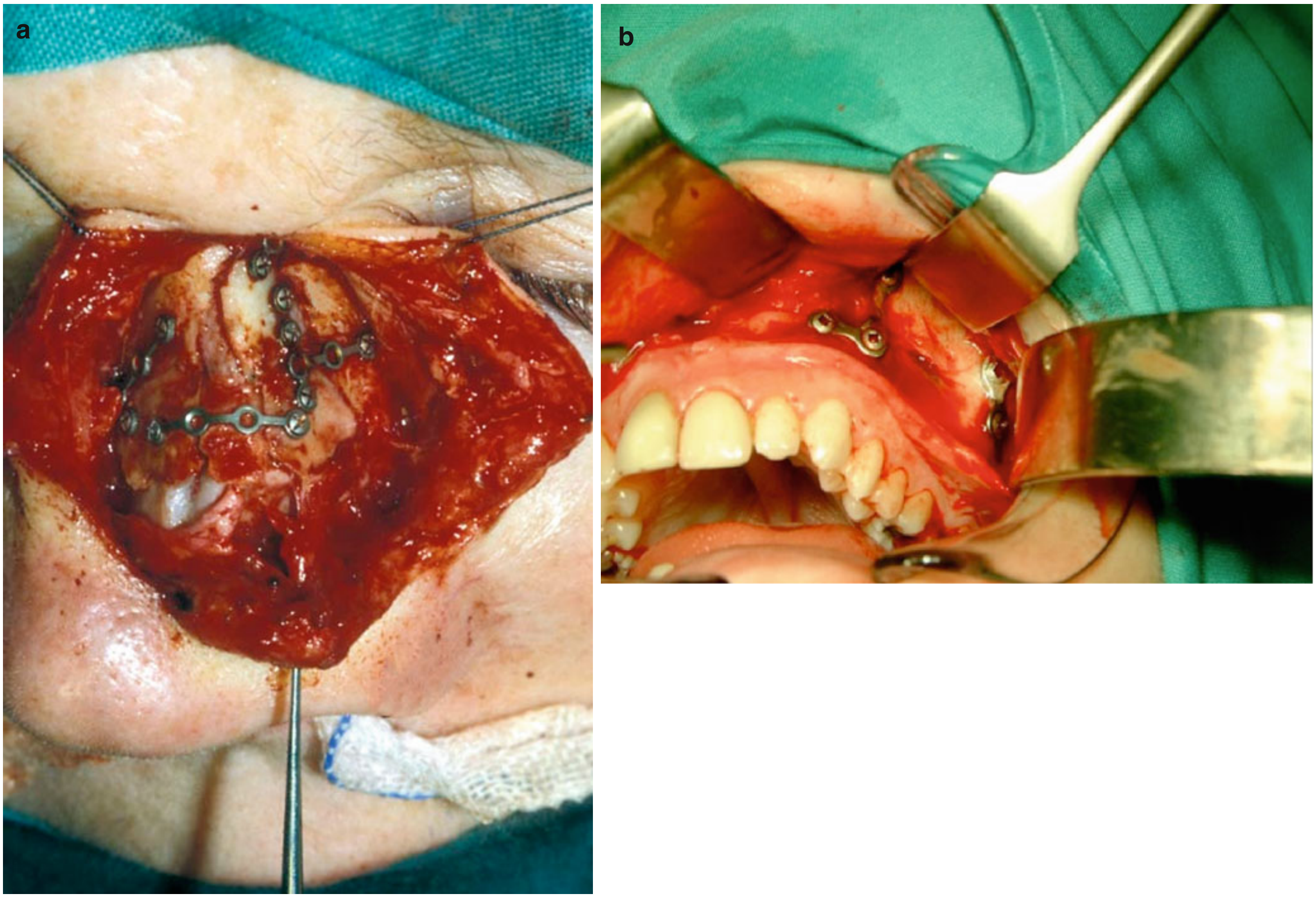

Fig. 17.4 Nasal skin varies in thickness. In patients with thin skin, both minor irregularities in the repair and the plates may be palpable. A careful assessment and meticulous layered closure is required. Compare this to the maxilla which is covered by the thicker tissues of the cheek. Although the mucosa may be thin, minor irregularities will not be detectable externally (**a**, **b**)

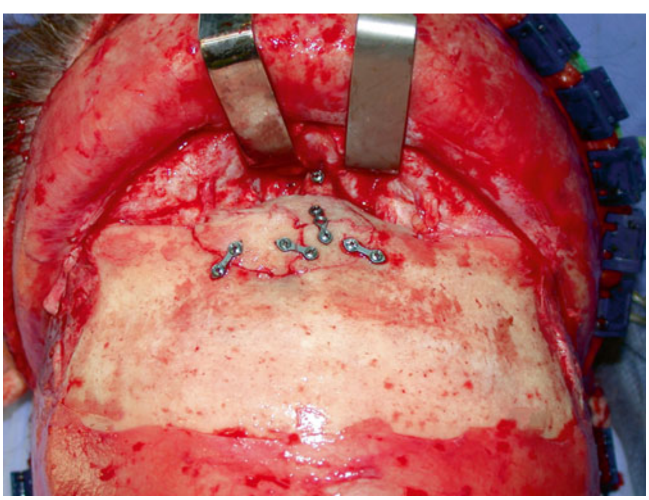

Fig. 17.5 A precise repair which will be covered by thick soft tissues

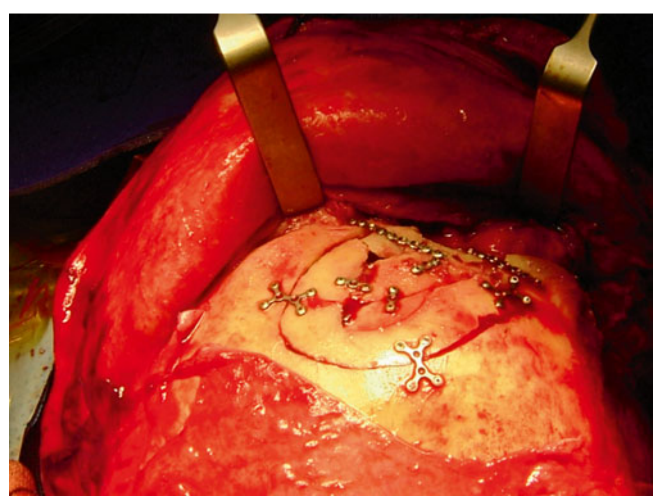

Fig. 17.6 A less precise repair and potentially palpable plates. Nevertheless this will give a good result due to the soft tissue coverage

17.2 Check the Zygomatic Arch Alignment, Cheek Projection, and Transverse Facial Width

Ideally there should be minimal bowing of the zygomatic arch. This can be surprisingly difficult to achieve. The arch is a relatively thin bone and can often bow along its entire length, even if it does not fracture. If it has fractured, the fixation plates need to be rigid enough. But if they are too thick they may be palpable through the soft tissues postoperatively. Failure to address the arch adequately can result in loss of cheek projection and an increase in the patient's transverse facial width.

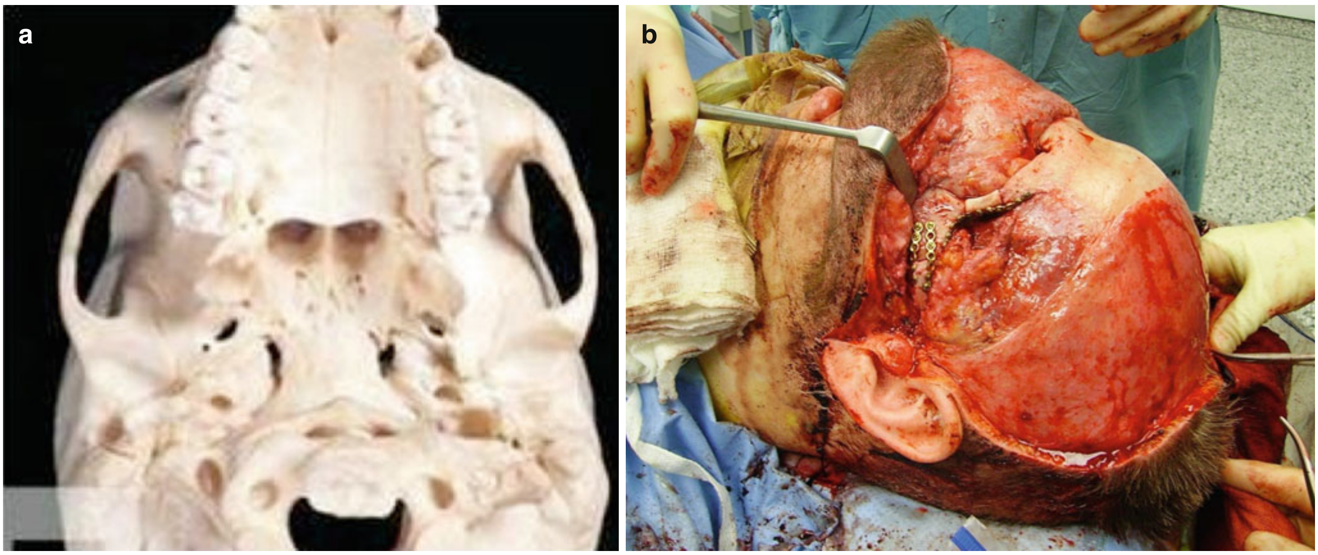

Fig. 17.7 The zygomatic arch is a relatively straight structure, with minimal bowing. This needs to be accurately restored to maintain cheek projection. Any fixation hardware needs to be sufficiently rigid, yet of a low profile to prevent an increase in the transverse facial width. Sometimes the arch can simply bow, without breaking. This still needs to be corrected (**a**, **b**)

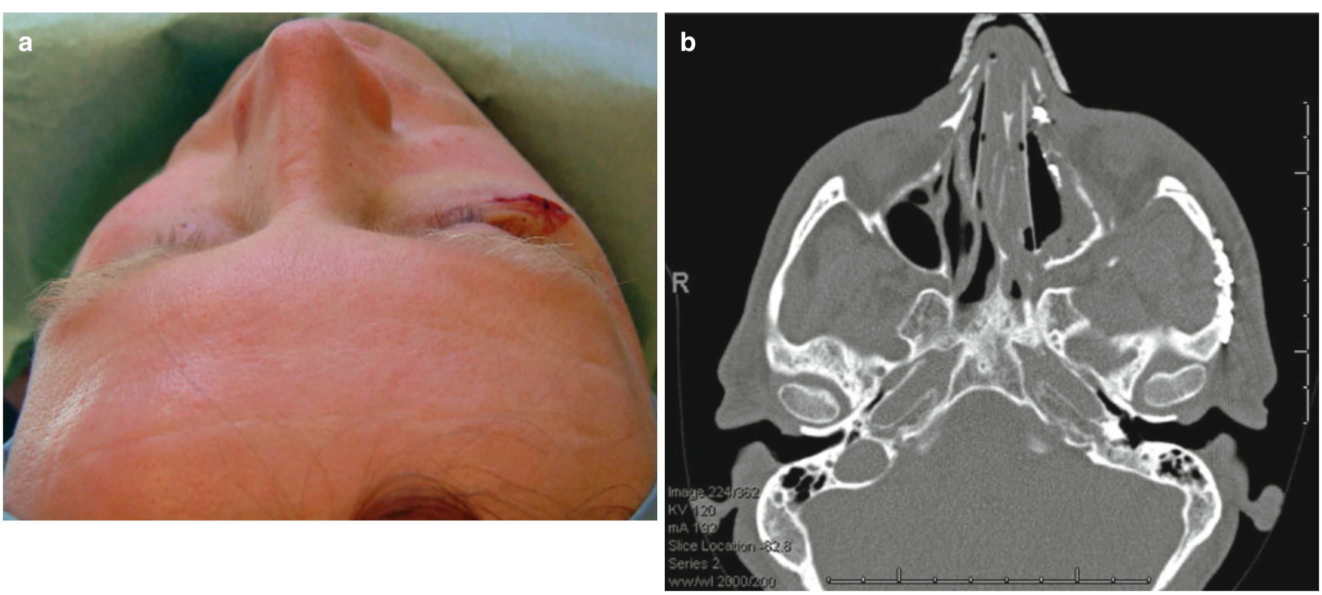

Fig. 17.8 Good cheek projection following repair (**a**). Even so, if one looks critically at the arch on the CT image (**b**), there is still a minor degree of residual deformation

17.3 Check the Lateral Orbital Wall

Correct orientation and alignment of the sphenozygomatic suture has been reported to be a good indication that the zygoma has been repositioned accurately. This is the site where separation usually occurs along the lateral orbital wall. Depending on the surgical access this may be difficult to visualise through a small incision. In these circumstances, steps in alignment can be detected by sliding a periosteal elevator along the wall. Beware comminution at this site; loose fragments may cause some confusion in appreciating overall alignment.

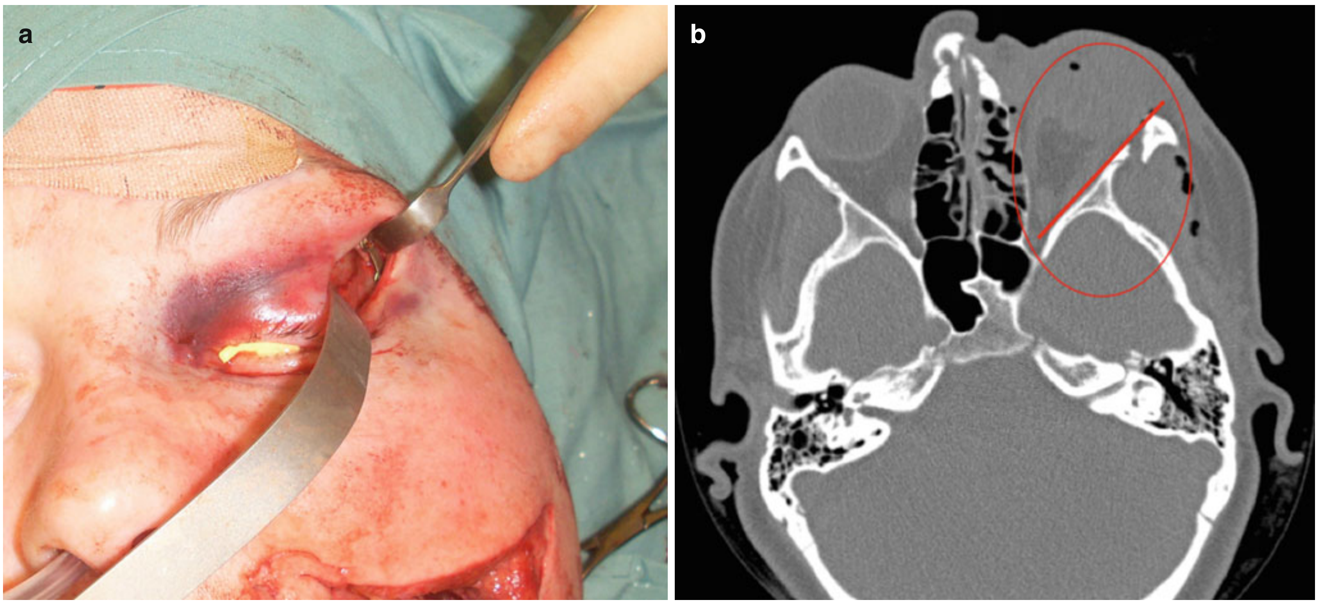

Fig. 17.9 Alignment of the spehnozygomatic suture is reported to be a good indication of accurate repositioning of a zygoma. This can often be seen when repairing the FZ suture, through a small incision (upper blepharoplasty in this case) (**a**, **b**). The *red line* indicates the lateral wall of the zygoma, and is a reliable marker for quality of reduction

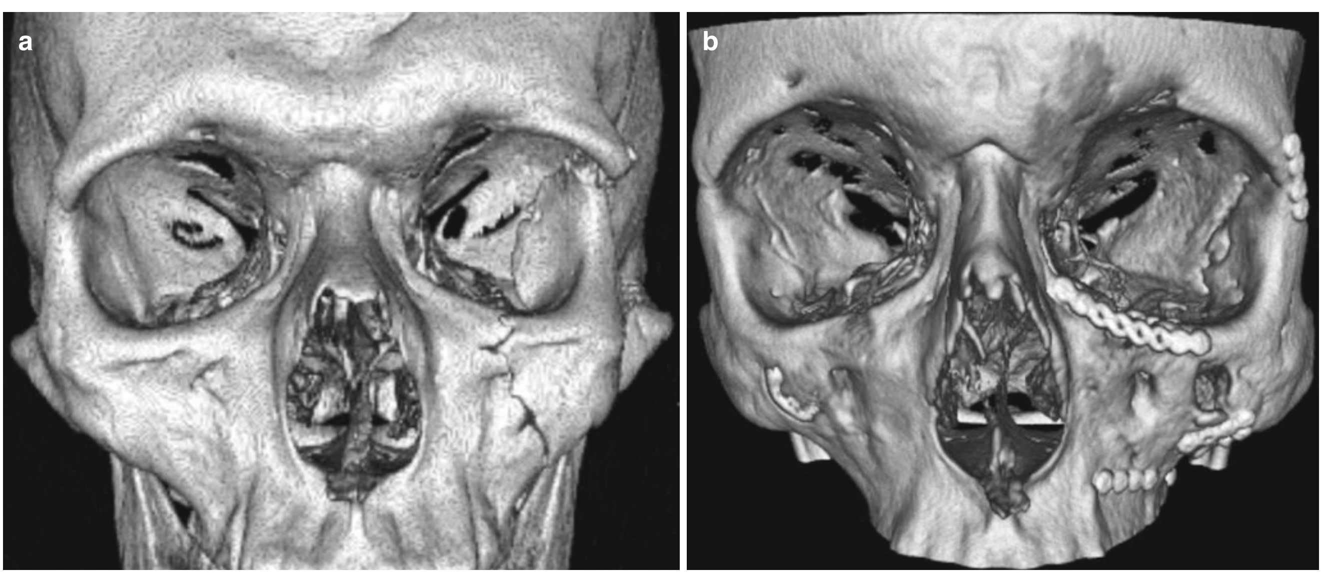

Fig. 17.10 Accurate alignment of the lateral orbital wall. Note the small fragment which initially created some confusion in assessment during the procedure (**a**, **b**)

17.4 Check Orbital Floor Plate Orientation and Its Alignment with the Posterior Ledge

Ideally, orbital floor plates should be positioned such that their posterior edge sits upon uninjured bone posteriorly (often referred to as the posterior ledge). If the entire periphery of the orbital defect has been clearly defined and the tissues retracted adequately, placement of a plate or graft should be relatively straightforward. However, with extensive defects, or when these involve more than one wall, confirmation of precise positioning at the time of surgery can be difficult. Such injuries are a good example of the benefits of navigational surgery and endoscopic assistance. If this is not available, ensuring the plate sits on the posterior ledge is a helpful indicator, but this in itself does not ensure it is correctly aligned with the medial wall. Adequate retraction of the soft tissues medially can be difficult, particularly if there is swelling. In a similar manner to the sphenozygomatic suture, sliding a periosteal elevator posteriorly along the plate should help detect malpositioning. Ideally it should slide onto the posterior ledge and up onto the medial wall smoothly.

Remember also your orbital anatomy and that the orbital floor slopes upwards from lateral to medial as well as anterior to posterior. With the newer precontoured plates now available, reproduction of the posteromedial bulge is part of the design. Although this makes accurate restoration of the orbital defect possible, there is very little scope for error in placement. With very deep defects, precise placement can be difficult as soft tissues can become trapped between plate and bone. In some cases there may be no posterior ledge, or it is too close to the orbital apex. Plates (or grafts) then need to be cantilevered and supported by the remainder of the defect. In these cases, precise anatomical restoration is unlikely.

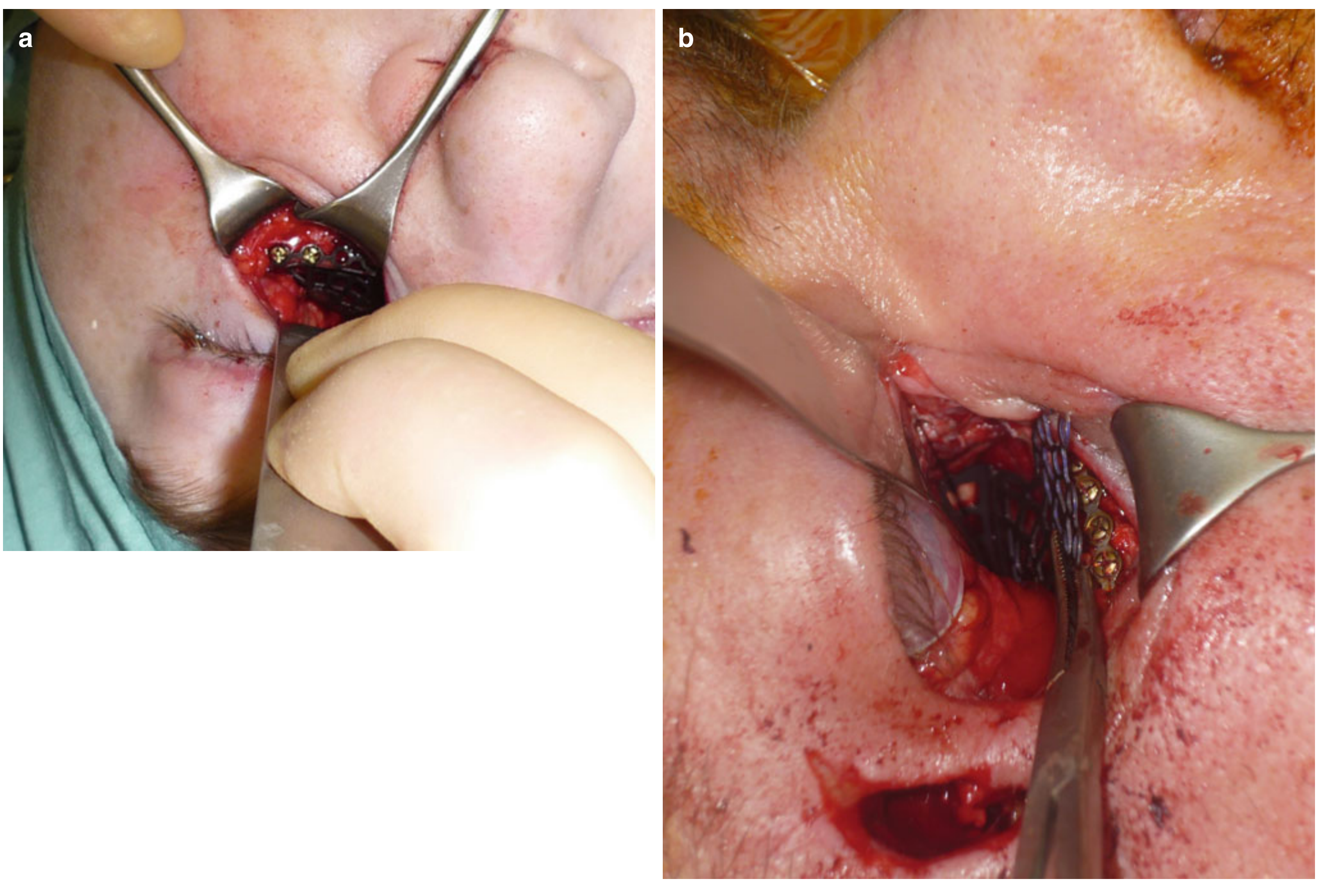

Fig. 17.11 Verification of precise plate positioning can be difficult, depending on the size of the defect and access. A headlamp may help (**a**, **b**)

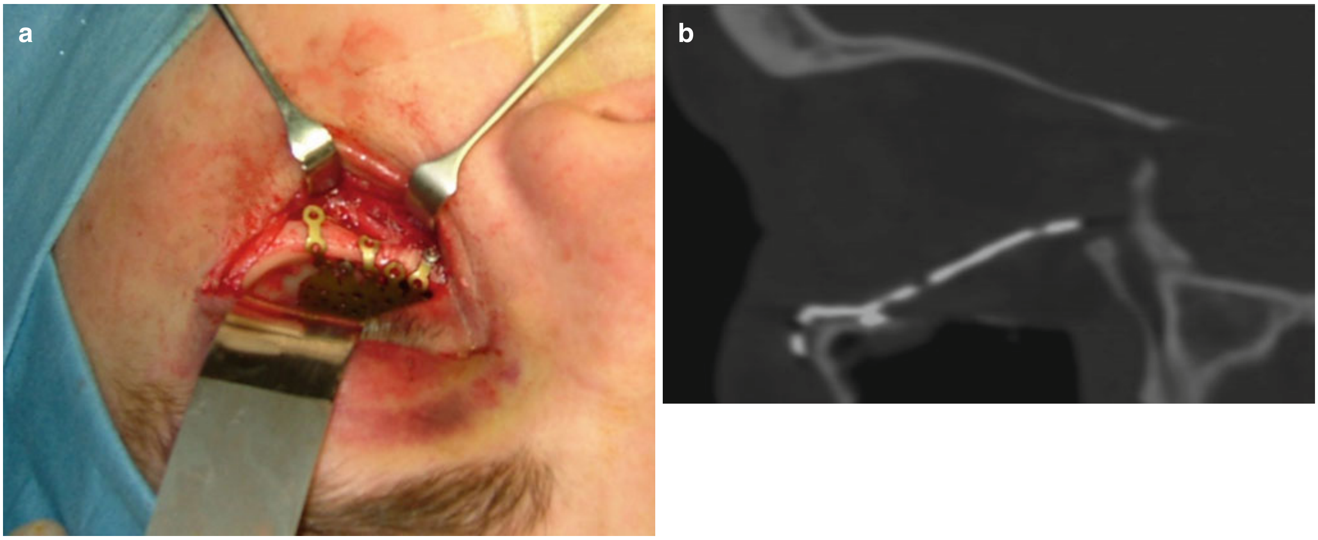

Fig. 17.12 Satisfactory visualisation through a much larger incision confirms accurate repair (**a**). The CT scan is of a different case (**b**). Note the built-in curvature of the plate. There is a small amount of soft tissue trapped between it and the posterior ledge, but this was clinically insignificant (there was no diplopia or enophthalmos). A satisfactory result

17.5 Check Pupillary Levels and Divergences

The pupils should ideally be at the same height (vertical dimension) and looking straight ahead. However, verifying pupil height can sometimes be difficult. Gaping infraorbital wounds or lid-swing approaches can cause the lower eyelid to droop with exposure of the lower limbus. This can create an illusion of dystopia, resulting in some confusion. Temporarily tacking the wounds with a suture can help in assessment. Ocular divergence can be detected by looking at the reflection of the operating light in the cornea. If the eyes are pointing in the same direction and at the same height the reflections should be in the same position in both corneas. If any divergence is seen, ensure that this is not secondary to entrapment. Perform a forced duction test, moving the globe in all directions, not just up. Dilation of a pupil can commonly be seen, but this is not necessarily a worrying sign.

Fig. 17.13 Assessment of globe position. The pupils are at a similar vertical height with a minor degree of divergence (look at the light reflection on the pupils). Note the dilated left pupil. This can occur commonly and is not a sign of blindness

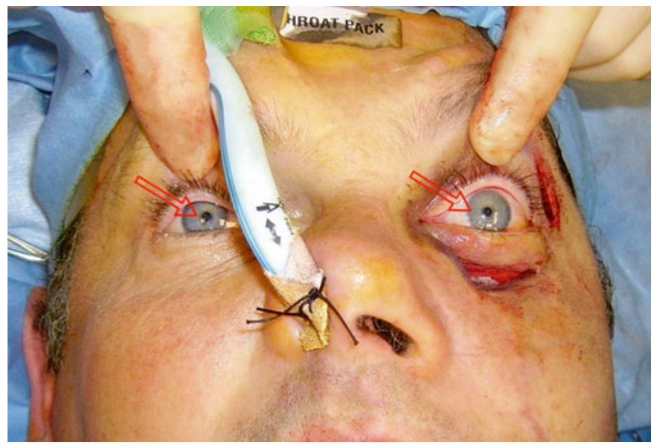

Fig. 17.14 In this case there is more exposure of the lower left iris, secondary to loss of support and drooping of the lower lid. This can make the globe appear dystopic. However, the light reflections are symmetrical. *Red arrows* point to the light reflex on the globes

17.6 Is There Any Enophthalmos or Proptosis?

Enophthalmos at the end of the procedure is clearly worrying (assuming it was not pre-existing before the injury) and needs to be addressed. However, minor degrees of proptosis following orbital repair may arguably be reassuring. Some degree of retrobulbar swelling is inevitable following dissection and retraction. Furthermore if the orbit has been anatomically restored there are no longer any large defects through which oedema can leak. So long as the proptosis is not excessively “tense,” this can be accepted. If unsure, use a tonometer to measure globe pressures. Enophthalmos is a common postoperative complication, which is permanent if not corrected. Permanent proptosis following orbital repair seems to be an extremely rare clinical entity.

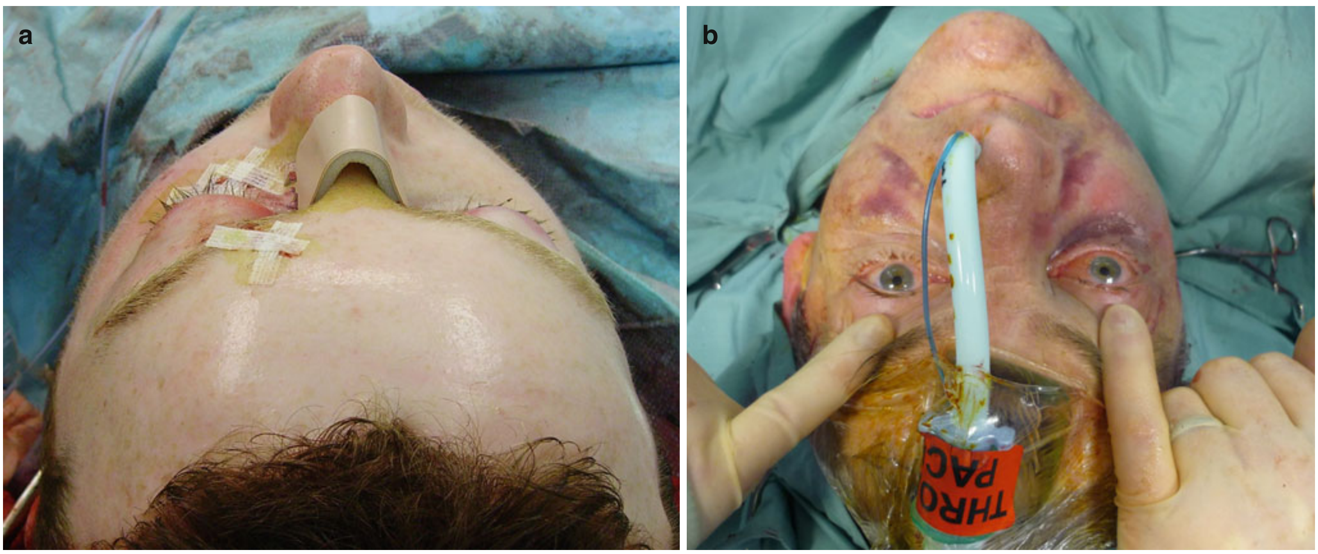

Fig. 17.15 Proptosis following repair of extensive fractures (**a**, **b**). So long as this is not excessive this may be a reassuring sign. As the swelling settles the globe will settle back. Permanent proptosis seems to be a rare complication

17.7 Do a Forced Duction Test

This is discussed elsewhere. Remember the eye moves in all directions. Tethering can also occur medially and laterally, depending on the fracture patterns. Therefore ensure medial and lateral movement is also unrestricted.

17.8 Check the Intercanthal Distance and Symmetry

Ideally this should be measured and compared to preinjury photographs of the patient. Intercanthal distance (ICD) is variably reported and a precise number cannot be relied upon. Rather it is just a useful guide. Preinjury photographs are very helpful in establishing facial proportions as a guide to accurate repair.

Fig. 17.16 The ICD can be assessed in many ways (measured, "rule of fifths", ICD:IPD ratio). Always remember to compare to preinjury pictures if possible

17.9 Check for Cerebrospinal Fluid Leakage

In the supine patient, cerebrospinal fluid (CSF) leakage may not be obvious as fluid may not necessarily leak out the nose. Gently clean and irrigate the nasal cavity to remove any clots. Then lightly pack the nose with dry ribbon gauze for a few minutes, withdraw and inspect. (Do not pack hard if anterior skull fractures are known to be present). Repeat this procedure several times. If there is significant leakage this will be obvious on the gauze.

17.10 Has the Nasal Septum Been Aligned and Supported Adequately?

A well-aligned septum is important for nasal projection and position. A comminuted septum can be virtually impossible to anatomically reduce and a degree of overlap of its fragments is inevitable. In such cases the aim therefore is to try and minimise this. Septal splints may help. Gently passing two periosteal elevators along each side of the septum or splint will detect any major deflections or buckling. These should be straightened if possible.

Fig. 17.17 Use of a traction suture to assess loss of nasal projection (**a**, **b**). Although the nose initially appears well projected, it has lost approximately 5 mm at the tip. Note return of the preinjury dorsal hump

17.11 Has Nasal Projection Been Restored and Does the Nose Appear Straight?

Compare the patient to preinjury pictures. This is important, as unfortunately some patients may see their injuries as an opportunity to have a longstanding problem corrected.

17.12 Check the Occlusion/Midlines and Mouth Opening

Preinjury photographs of the patient smiling can help verify the upper dental midline. The occlusion should be checked, not only as a static bite, but also in lateral excursions (group function/canine guidance), using wear facets as a guide. If in doubt, impressions can be taken in advance or at the beginning of surgery and study models quickly cast.

17.13 Is Bone Grafting Required?

Bone grafts may be required if bone has been lost, or is so extensively comminuted that it cannot be repaired.

Fig. 17.18 A septal traction (*arrow*) suture, useful in assessment

Fig. 17.20 Bone graft to nasal dorsum

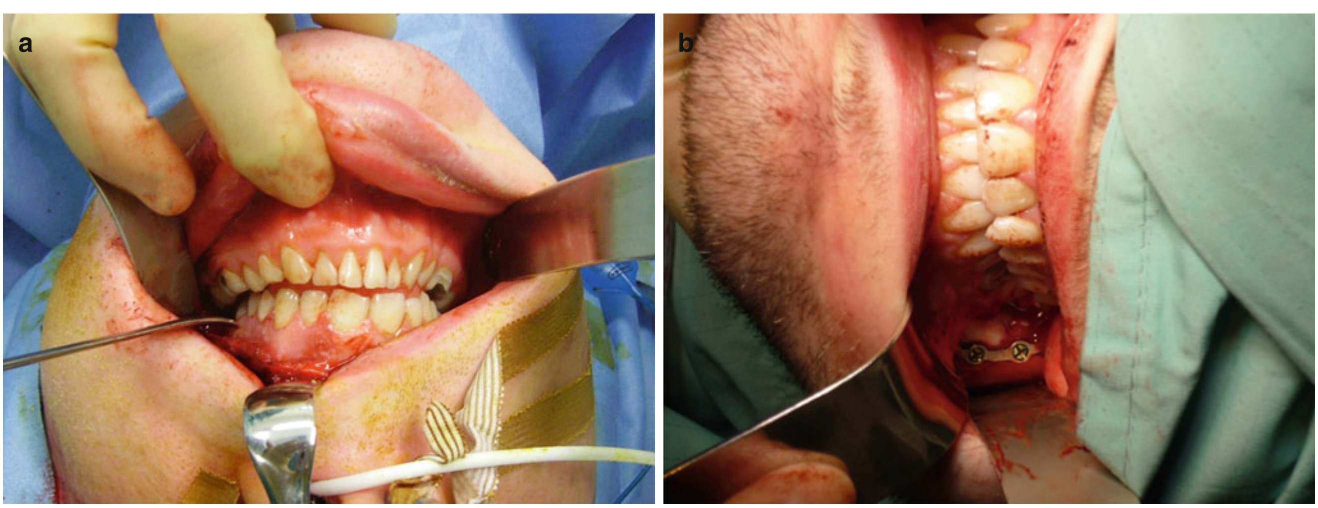

Fig. 17.19 Initial assessment of the occlusion in a Le Fort fracture, with midline shift and maxillary retrusion (**a**). Satisfactory restoration of the occlusion following repair of a left mandibular angle fracture (**b**)

17.14 Does the Patient Require Postoperative Hooks/Arch Bars and Intermaxillary Fixation?

Consider intermaxillary fixation (IMF) if there are fractures of the condyle, more than one fracture of the mandible, comminuted fractures of the mandible or if there are midface fractures.

17.15 Have the Soft Tissues Been Resuspended?

Resuspension is important to avoid ptosis of the tissues. Key sites include:

1. The Forehead
2. Temporalis fascia
3. Cheek
4. Chin

The aim of resuspension is to "defy gravity" when the patient is upright. Consequently the sutures do not need to be too tight. If so this can raise the tissues too much, an appearance sometimes referred to as the "frightened rabbit" look!

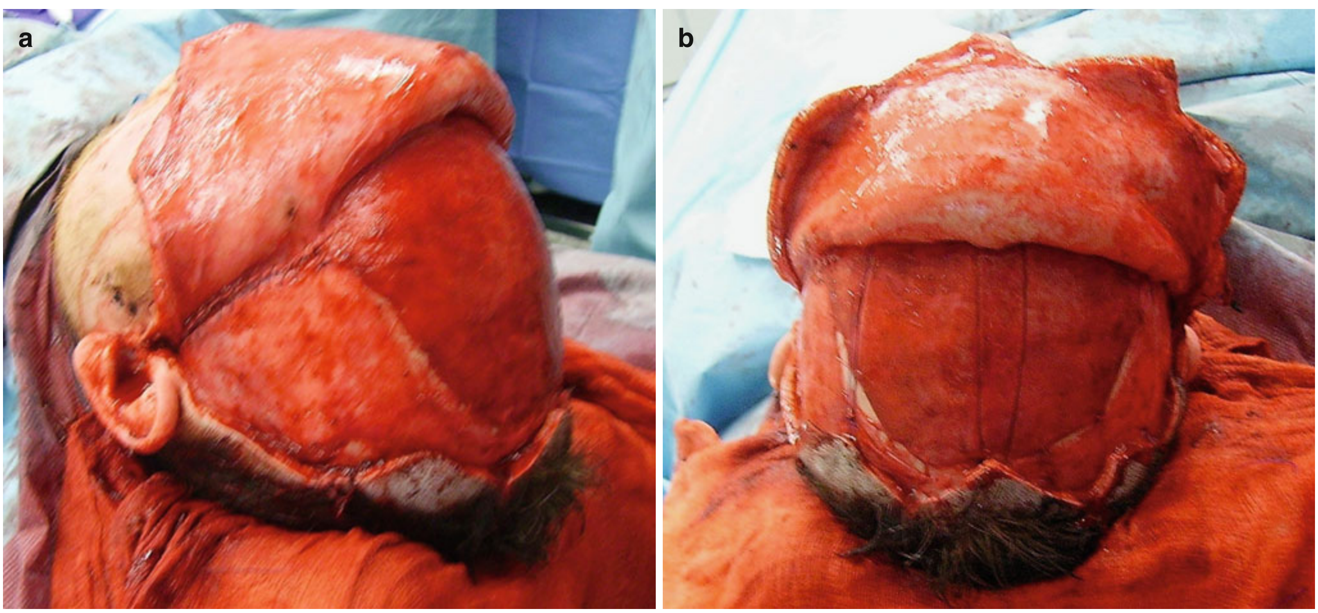

Fig. 17.21 Meticulous resuspension of the soft tissues is crucial for a good result. Many techniques have been described using various anchoring devices. The aim is not to over close the tissues, but rather to prevent them sagging post operatively (**a**, **b**)

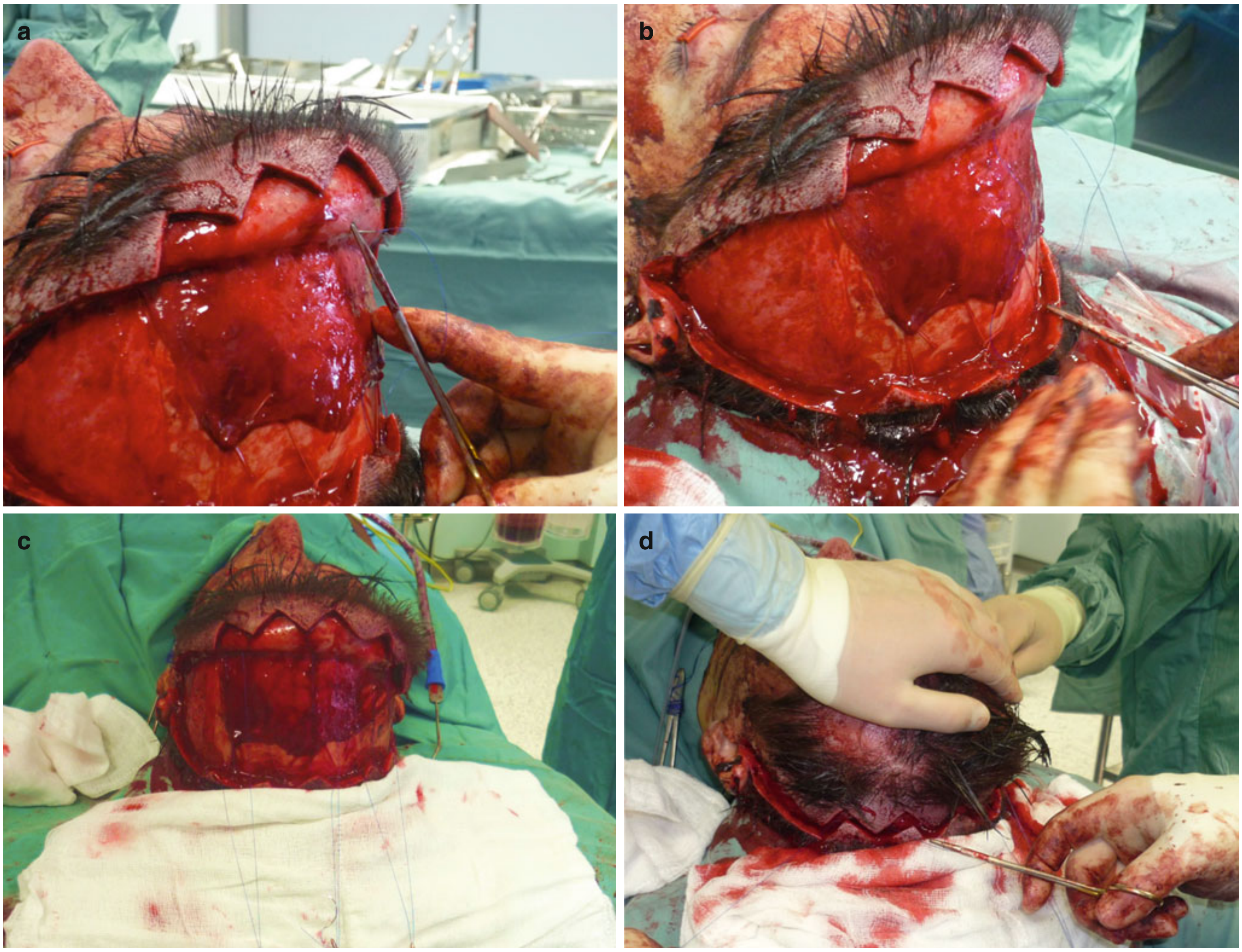

Fig. 17.22 Forehead resuspension using 3.0 prolene (**a**, **b**). Multiple sutures are passed through the aponeurosis before tying. Be careful not to take too big a bite; this can result in puckering of the forehead skin

Suggested Reading

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18 Some Useful Adjuncts in Repair

Michael Perry and Simon Holmes

Repairing facial injuries involves more than just plating fractures and suturing wounds. A number of additional skills and procedures may also be required, some of which are described here. These are required on a case-by-case basis and are not limited to one particular type of injury.

18.1 Globe Protection

Protection of the globes is the responsibility of the surgeon. Although the eyes are often covered and protected by the anaesthetic team following induction of anaesthesia, it is the surgeon's responsibility to ensure that this protection is adequate and will last the entire duration of the procedure. In most cases adequate protection can be provided simply by applying a suitable protective ointment to the eyes, and then taping the eyelids shut. This may take various forms, but usually involves a combination of padding and tape. However, this is a preliminary measure and needs to be carefully checked, especially if the face is to be cleaned. It must be remembered that some antiseptic solutions used to clean the face contain chemicals which can be quite irritant to the conjunctiva (such as alcohol). These solutions can pool around the medial canthal region and if the protection is not watertight eventually drain onto the surface of the globe, irritating the eye for the duration of the procedure. It is important therefore not to use an excessive amount of antiseptic solution when cleaning the face and to dry off any excess where it collects. Similarly, applying a plaster of paris splint to the nose can result in chemical burns to the eye if this is dripping wet when placed. Before applying the plaster squeeze it between two dry gauze swabs to remove any excess fluid.

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The use of protective ointment, pads and tape is usually satisfactory when surgery to the periorbital region is not required. However when this or orbital exploration is anticipated, such protection is not possible and an alternative required. Protective "eye shields" provide another simple and effective way to protect the globes. It is important to remember to moisten the entire fitting surface of the shield with protective cream prior to placement, to avoid corneal abrasions. Placing dry rubber or silicone directly on the globe may abrade the cornea. Unfortunately, lubricant often makes these eye shields somewhat slippery and they can easily dislodge during surgery. Just because the shield has been placed correctly at the beginning of the procedure does not mean that it will remain there. It is therefore important to be mindful that they can displace and to regularly check during surgery.

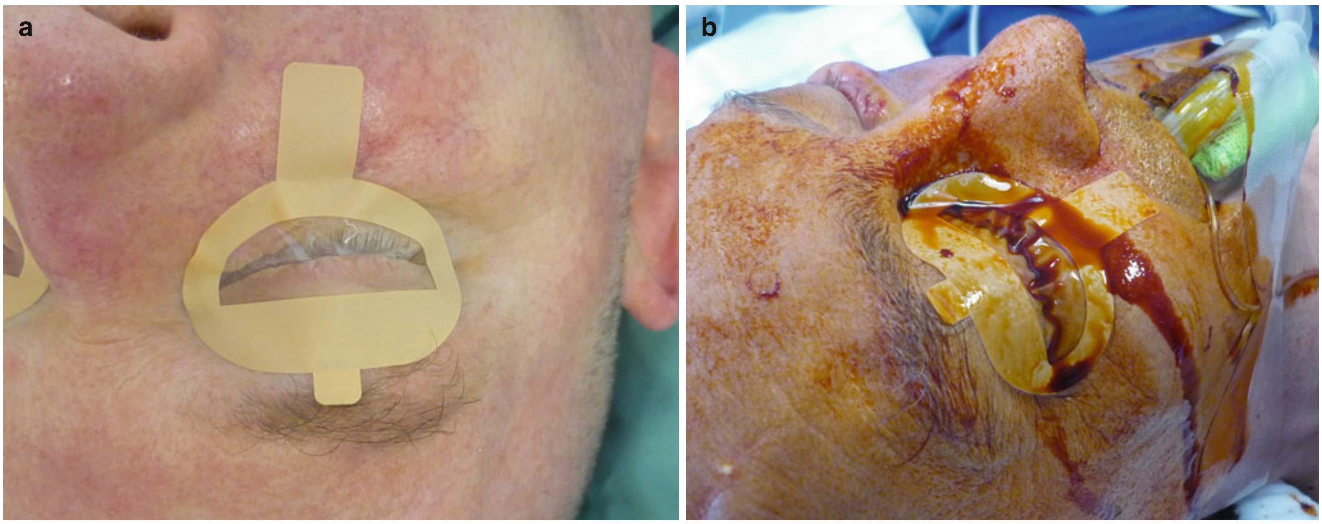

Fig. 18.1 (**a**, **b**) Adhesive eye patches. These must be fully attached around their periphery to protect the globe from irritant fluids

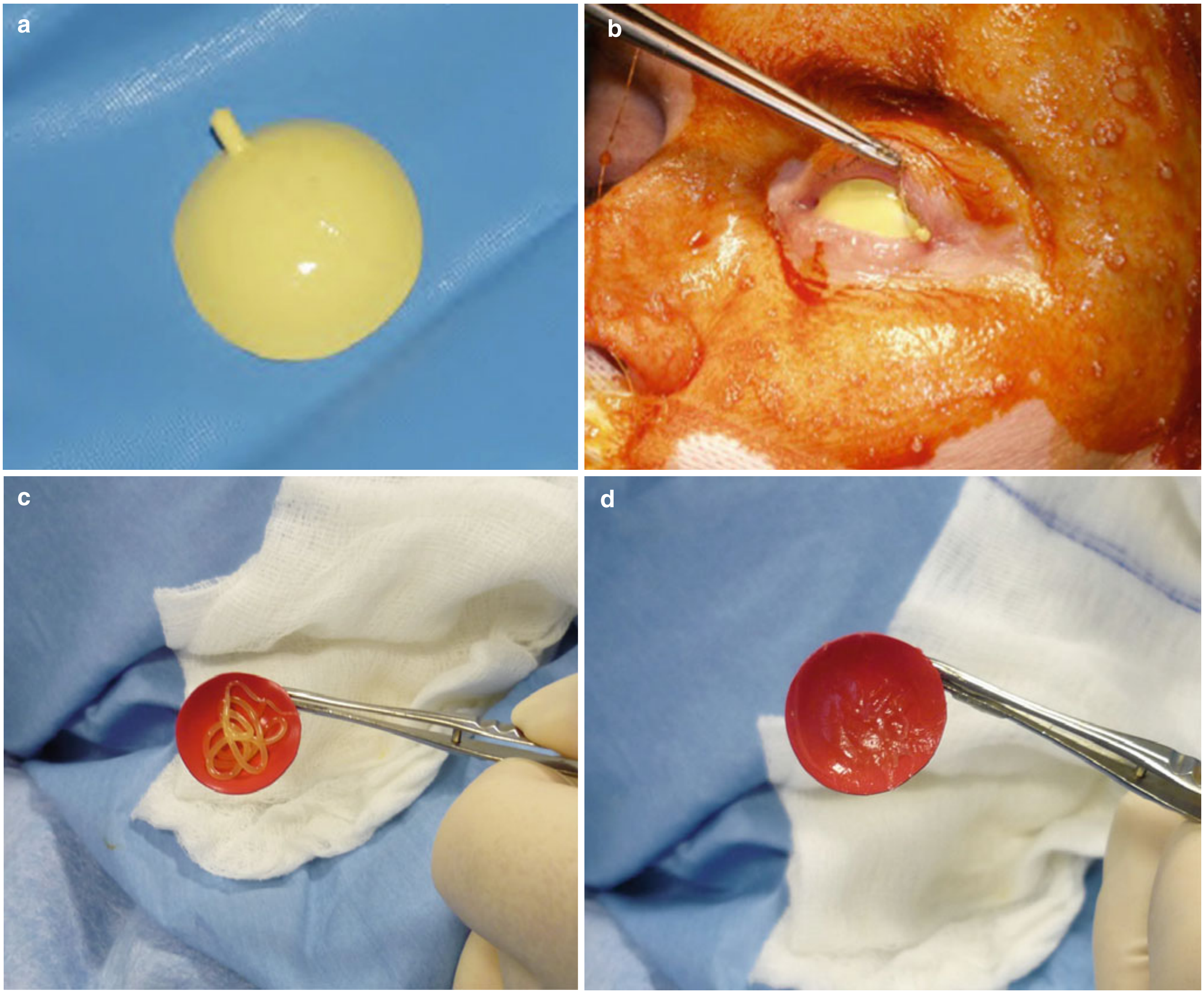

Fig. 18.2 (**a**–**d**) Silicone/rubber eye shields. A good coating of lubricant should be applied to the fitting surface before placement

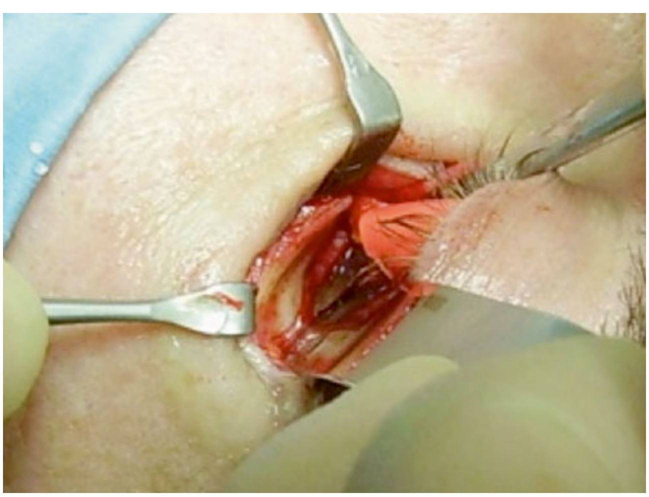

Fig. 18.3 Unfortunately, this makes them easy to dislodge

18.1.1 Tarsorrhaphy (Temporary)

Displacement of eye shields and eye pads can occur when surgical procedures require considerable access and retraction of the soft tissues. The coronal flap, when fully reflected, can often dislodge any insecure eye protection. For this reason, some surgeons prefer to carry out a temporary tarsorrhaphy as shown. Essentially the upper and lower eyelids are loosely sutured together in the closed position. Protective ointment is still applied to the globes with or without the use of eye shields.

Eyelid and periorbital skin is the thinnest skin in the body. Any sutures placed here can therefore easily tear through the tissues. For this reason the suture needs to pass through the underlying tarsal plate of both eyelids. This needs to be placed gently.

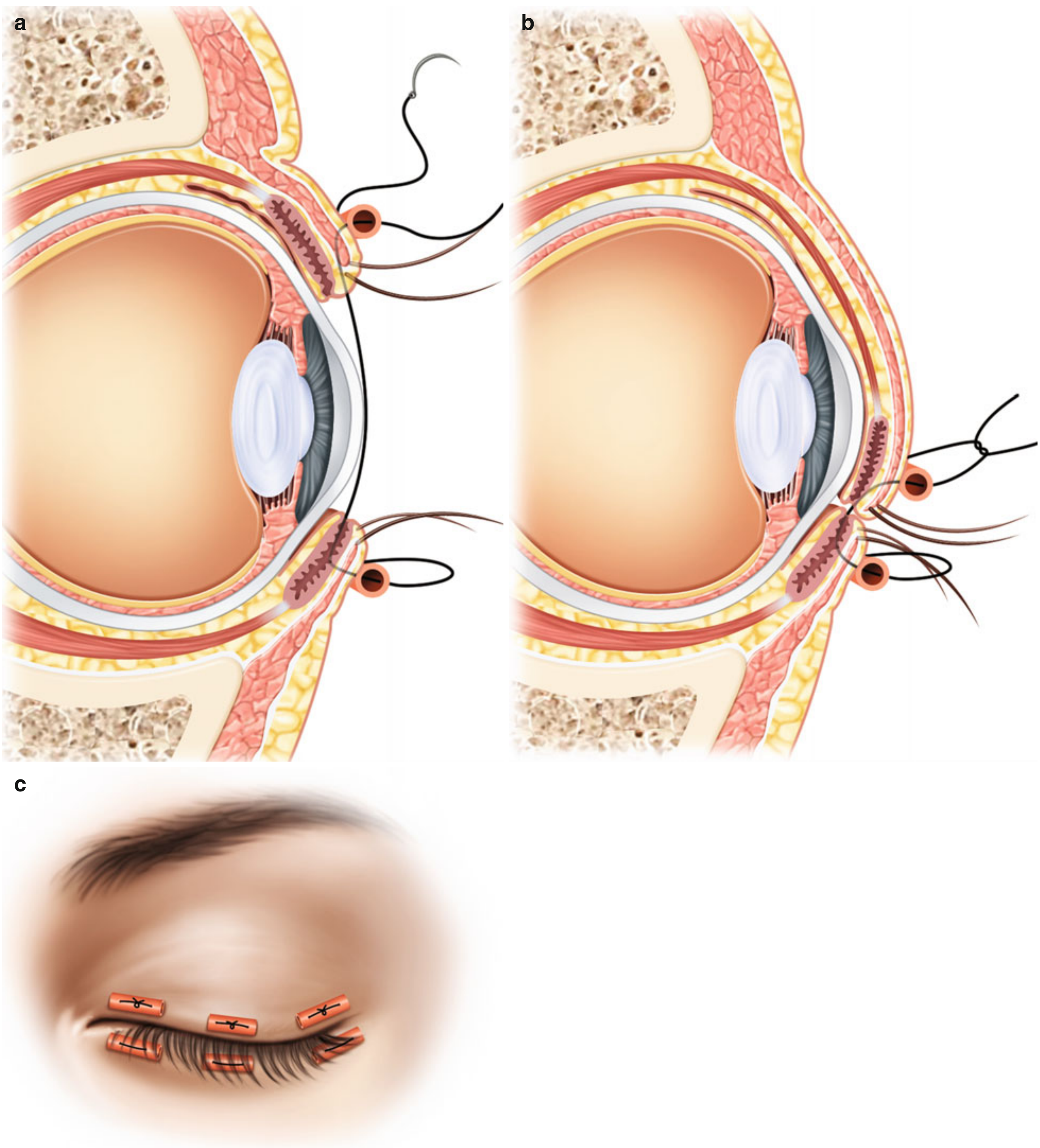

Fig. 18.4 (**a–c**) Tarsorrhaphy sutures. These must include the tarsal plate to avoid "cheesewiring" through the thin eyelid skin

Because of its handling properties, silk is a good choice, but this is not essential. The suture is placed in a horizontal mattress configuration, passing through the eyelid skin and tarsal plate, being careful not to pass through the entire thickness of the eyelid. The tip of the needle is brought out immediately adjacent to the eyelashes such that when the tarsorrhaphy is tied and the eyelids closed, the suture is unable to rub on the eye. As an additional precaution, the points of entry and exit of suture should be placed medial and lateral to the iris so that any inadvertent contact is not directly onto the cornea.

Very often a small plastic or rubber tube may be used to protect the eyelids from too tight a suture. The eyelids only need to be held gently in the closed position so sutures are tied loosely.

Case 1

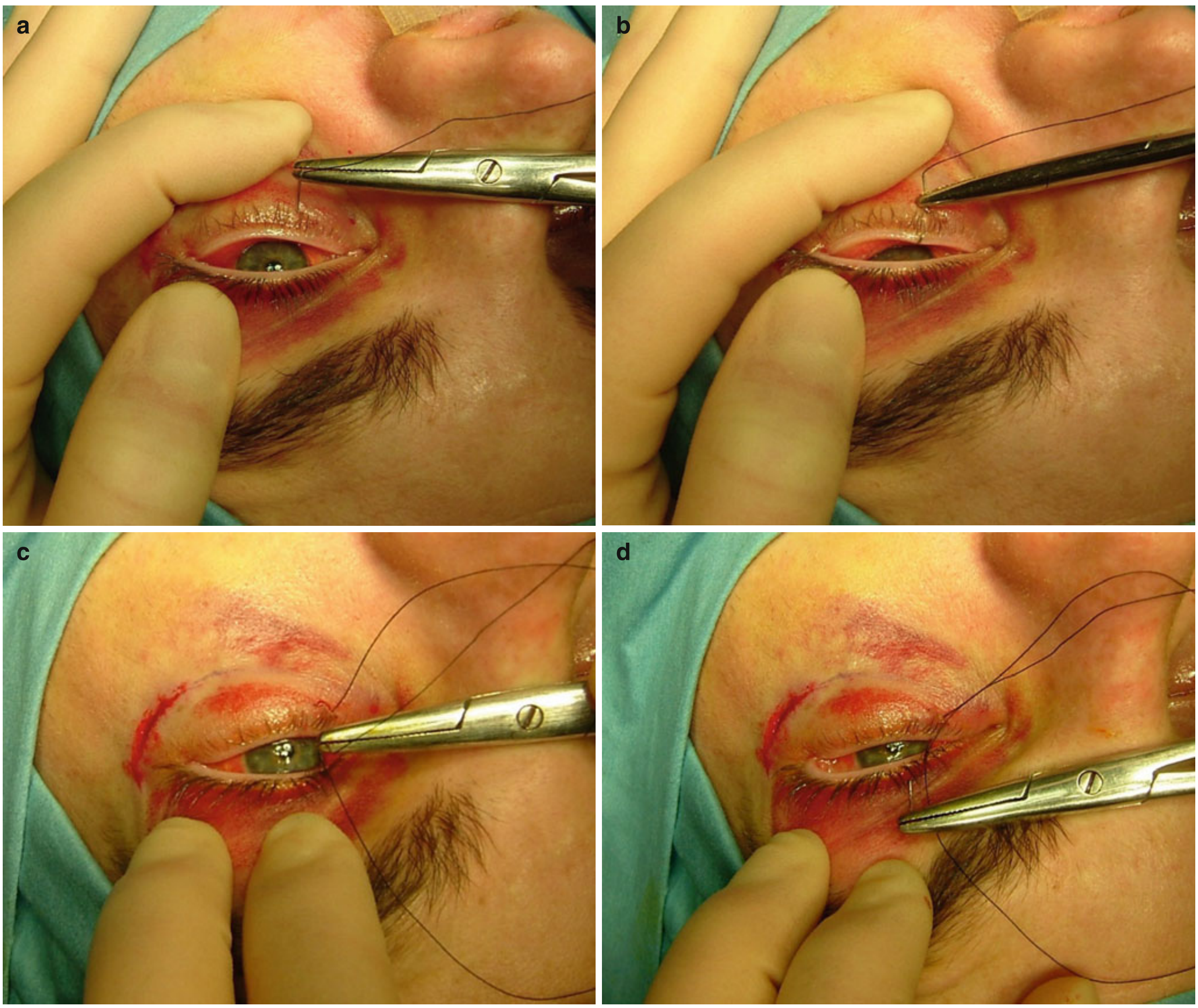

Fig. 18.5 (**a**–**g**) Sequential steps in tarsorrhaphy

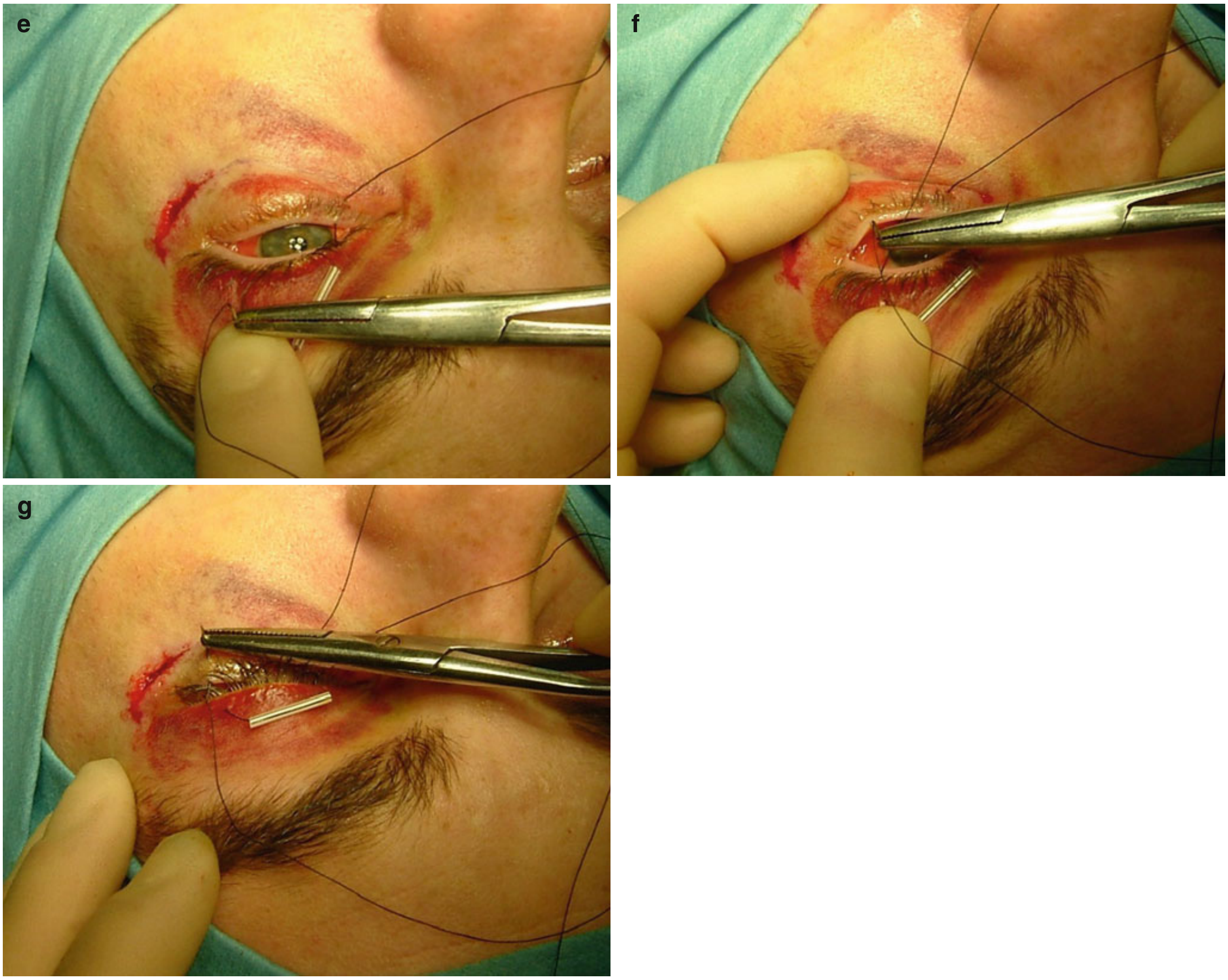

Fig. 18.5 (continued)

Case 2

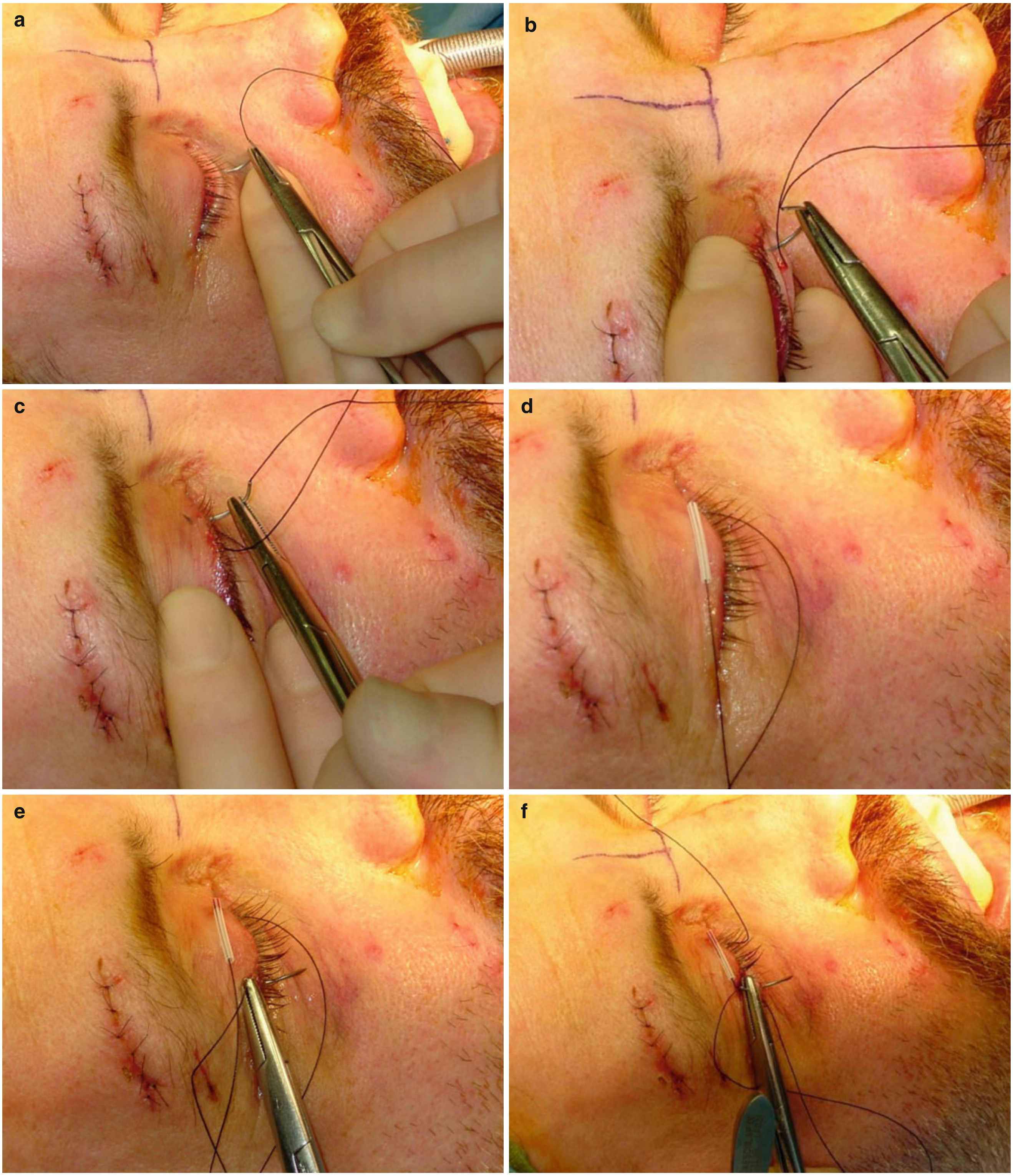

Fig. 18.6 (**a**–**h**) Temporary tarsorrhaphy. The plastic tube from an IV cannula can substitute for rubber tubing

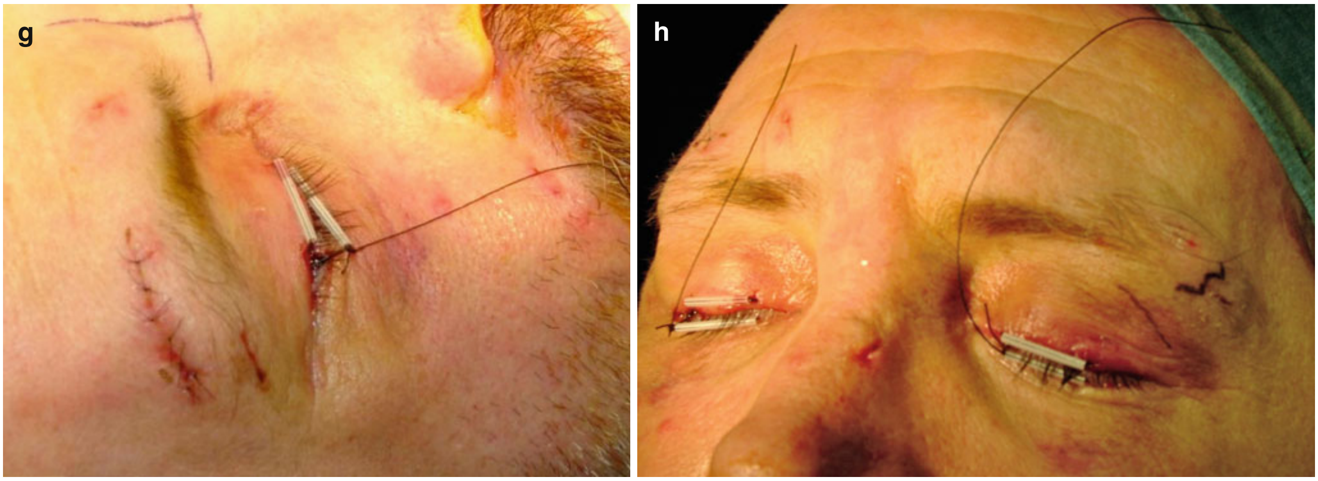

Fig. 18.6 (continued)

A number of variations in this technique exist. Which is used is largely a matter of personal preference. So long as the sutures are placed delicately, do not come into contact with the globe and do not damage the lids, any of these will do the job adequately.

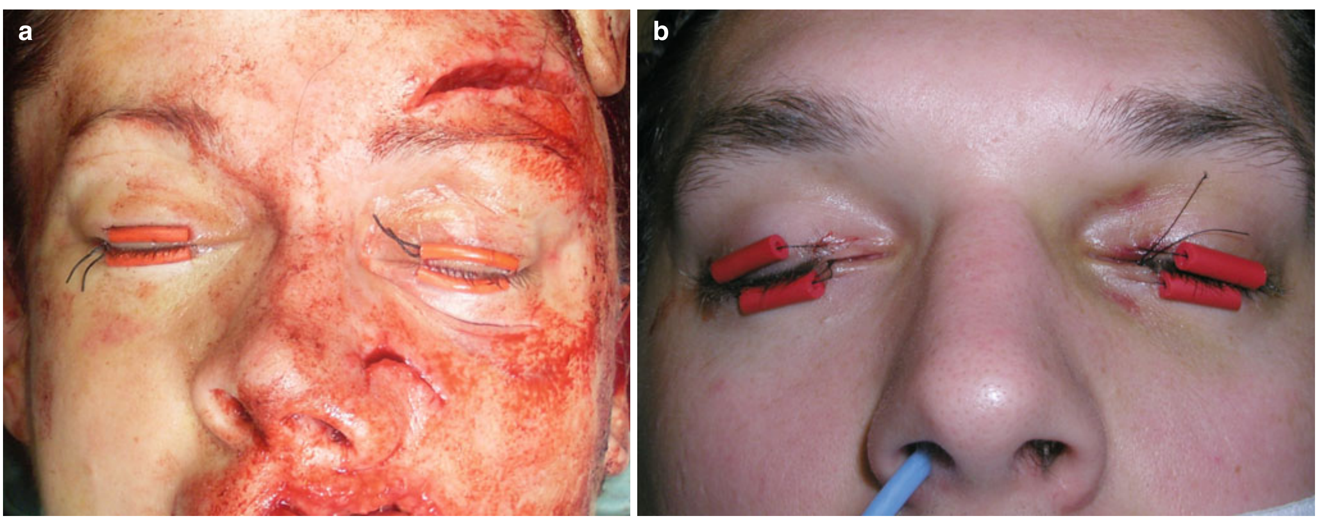

Fig. 18.7 (**a, b**) Temporary tarsorrhaphy using fine rubber tubing

Case 3

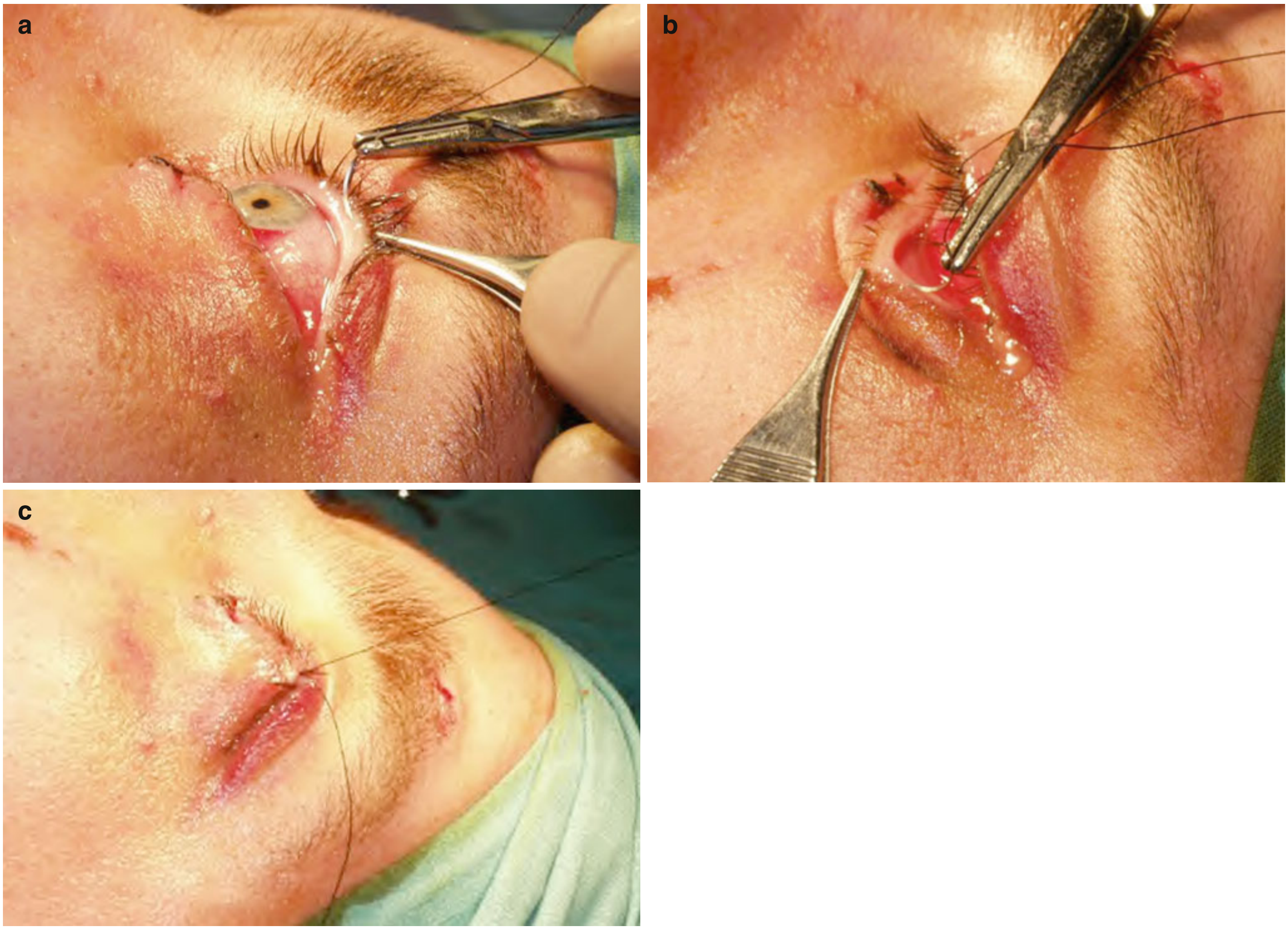

Fig. 18.8 (**a**–**c**) Alternative technique. The needle is passed parallel to the eyelid margin, engaging the lower end of the tarsal plate

If the first "bite" of this suture starts in the lower eyelid, the resulting knot will also be along the lower eyelid. If this suture is cut long, this can be used as a traction stitch if a lower eyelid incision is required. Of course this procedure cannot be undertaken if a transconjunctival approach is to be used to access the orbit.

Case 4

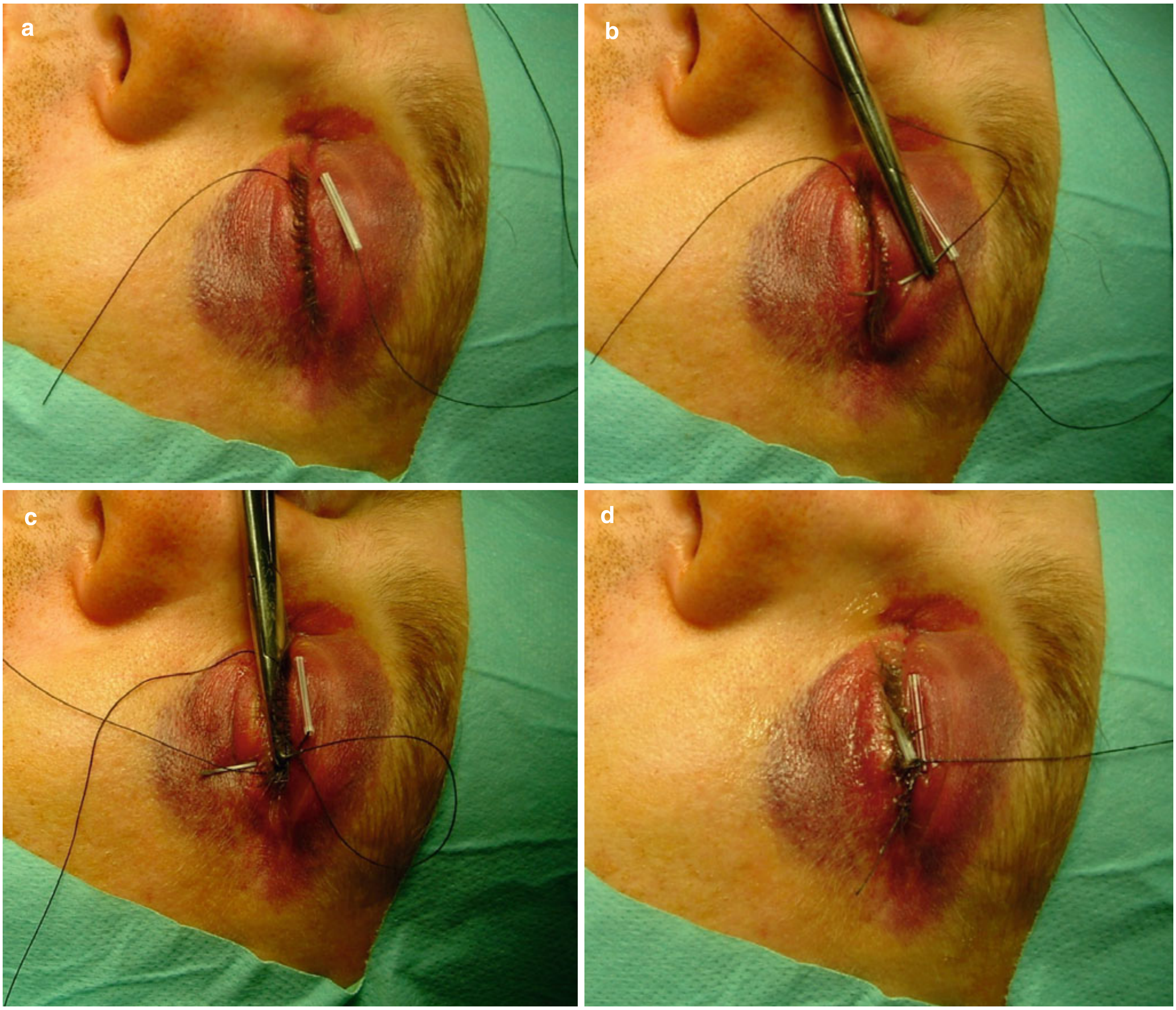

Fig. 18.9 (**a**–**d**) Temporary tarsorrhaphy

Case 5

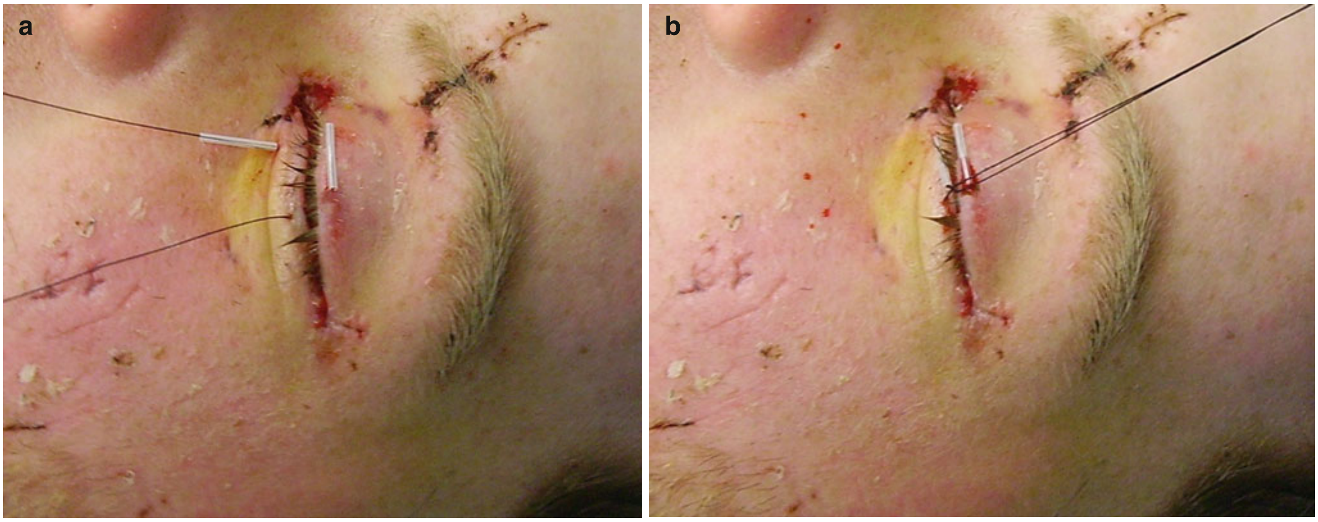

Fig. 18.10 (**a**, **b**) Temporary tarsorrhaphy

18.2 Bone Grafts

With the development of stronger fixation systems, there is now less need to carry out primary bone grafting at the time of fracture repair. Nevertheless, with extensively comminuted fractures, or where there has been loss of bone, primary grafting should be considered. Today bone grafts are more commonly used in secondary reconstruction. A number of donor sites are available. These include the calvarium, mandible, rib and the pelvis. Each has its own set of advantages and disadvantages. Unless the defect is very large, most primary bone grafts used in trauma are free, nonvascularised grafts.

If a block of bone is used, the key to success is to rigidly fix the graft to the adjacent bone and ensure it is covered with healthy vascularised soft tissue. Avoidance of contamination and infection is also essential. The general principles of placing a bone graft is as follows. Following placement of the incision, a full thickness flap is gently raised and mobilised until there is enough soft tissue to provide tension free closure. The graft is then harvested and shaped to provide a good fit into the defect. It is then rigidly fixed. The flap is reposition and closed. If tension free closure is not possible, a local flap may be required.

18.2.1 Iliac Crest (Block Bone)

The aim in this procedure is to harvest a partial thickness block of bone from the ilium, usually composed of its inner cortical and cancellous bone. This involves exposure of the bony pelvic cavity, with its attendant risks. Although the term "Iliac crest" is commonly used, in many cases where free nonvascularised or particulate bone grafting is required, the crest itself can, in fact, be left. This is because the crest receives the insertion of several large muscles, the attachments of which should be preserved whenever possible.

However, some major reconstructions may require the crest itself, in order to take advantage of its natural curvature. This is a common choice in mandibular and maxillary reconstruction following ablative surgery. More commonly in trauma (with smaller defects) a piece of the inner table of the iliac bone will suffice. Nevertheless, this site can usually provide a sizeable piece of nonvascularised bone for grafting.

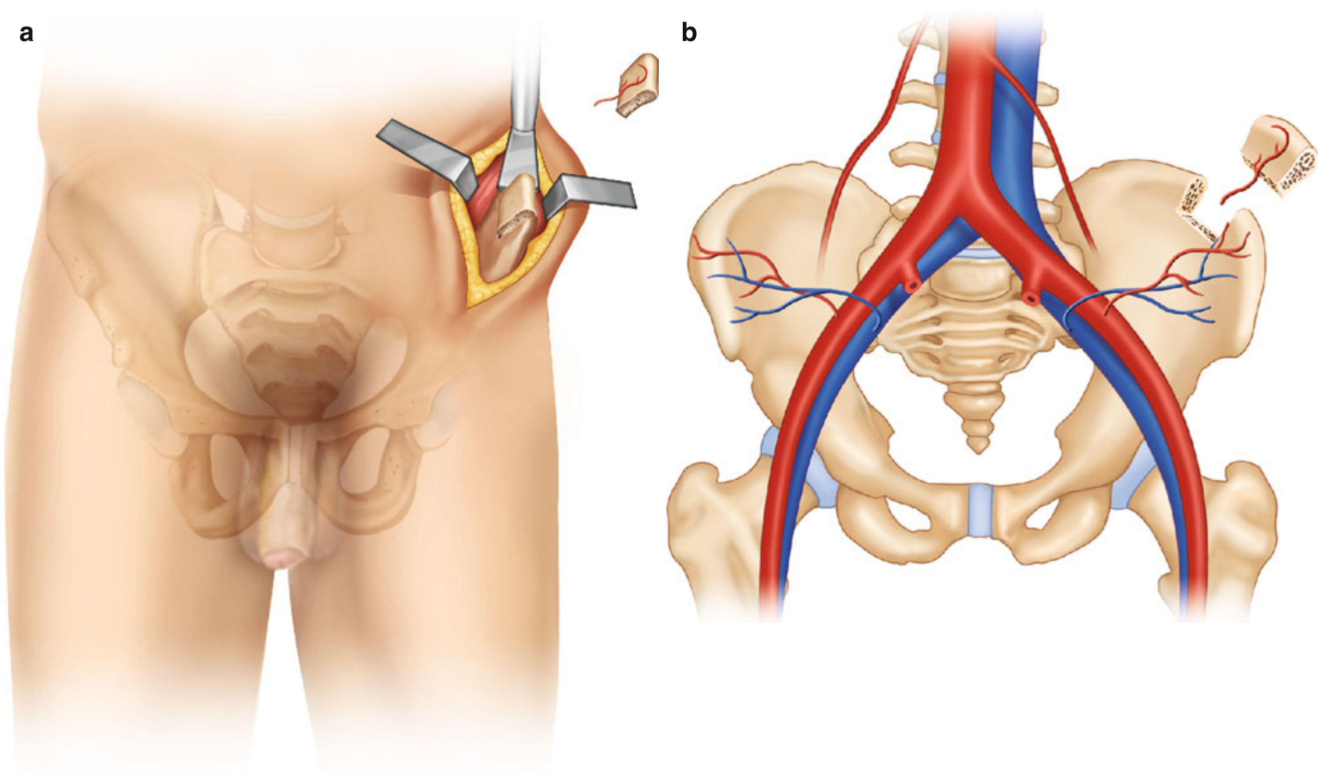

Fig. 18.11 (**a**, **b**) Deep circumflex iliac artery (DCIA) flap. This is a vascularised "free-flap," which includes the curvature of the iliac crest. Potentially a very large graft, but requires detachment of a number of large muscles

The "iliac crest graft" used in trauma is therefore usually a free nonvascularised graft, as distinct from the vascularised deep circumflex iliac artery (or "DCIA") flap more commonly used following ablative surgery. However the latter may still be required occasionally.

The nonvascularised iliac crest graft is mostly composed of thick corticocancellous bone. This graft is best suited for non–load-bearing repairs or reconstructions. Examples include repair or secondary reconstruction of the orbit, frontal sinus or dentoalveolar bone, although others exist. Alternatively, particulate cancellous bone may be used to fill bony voids. Unfortunately, resorption is a complication of all free bone grafts, the extent of which is unpredictable. This is a drawback when using bone to augment surfaces (such as malar augmentation).

Much of the bone resorbed is from the looser cancellous portion of the graft. Sometimes resorption can be minimised by compacting the cancellous bone prior to graft placement, or by removing it completely and using just the more compact cortical bone. The graft is then only suitable as a partition, for example in orbital reconstruction. It has minimal volume.

A number of techniques are available to harvest a block of bone. Generally speaking, the crest is exposed and temporarily removed to improve access to the ilium. It is then replaced at the end of the procedure.

Ideally it is best not to place the incision along the iliac crest itself. This can result in a painful stretched scar. Fortunately, the laxity of the soft tissues allows an incision to be placed approximately 1–2 cm medial or lateral to it.

Following incision, the underlying iliac crest is exposed. A "coffin-lid", or hinged approach, provides access to the inner table. The crest is separated from the deeper bone and hinged to one side, exposing the cancellous bone and cortical plates either side. This involves placement of two bone cuts, perpendicular to the long axis of the crest (or slightly angulated to allow the lid to be wedged back during closure). These are then joined together using an osteotome. The "lid" of the crest is then cut and hinged medially, while retaining its periosteal attachment to the inner table of bone.

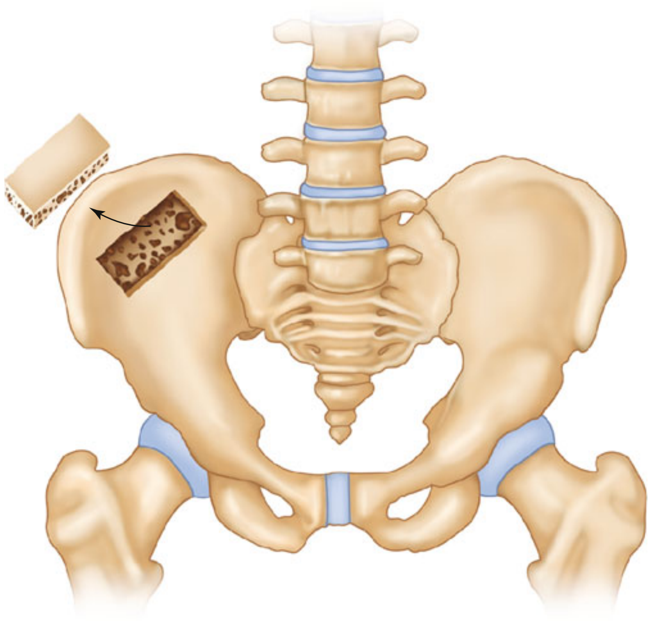

Fig. 18.12 Corticocancellous bone is a nonvascularised graft which can preserve the crest and its muscle attachments

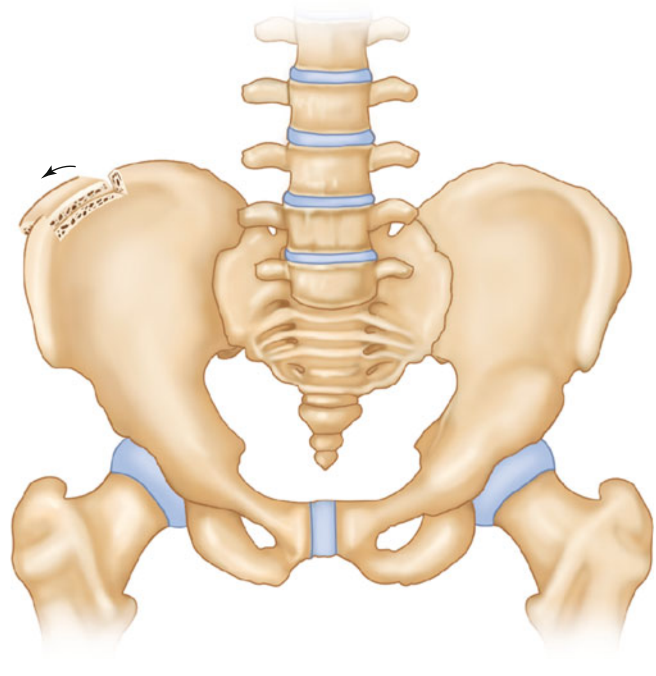

Fig. 18.13 "Coffin-lid" approach where the crest is hinged medially (or laterally) to improve access to the ilium

As the “lid” is mobilised medially it begins to lift the thick periosteum off the inner table of bone. This is an important plane to maintain, particularly when using sharp or cutting instruments. On one side of this plane is the inner table of bone (soon to be harvested); on the other side, deep to the periosteum, is the iliacus muscle and pelvic contents. Enough periosteum is stripped away medially to define the margins of bone graft.

Safe retraction of the pelvic contents is obviously essential prior to osteotomising the bone. Packing gauze into this medial subperiosteal layer is a relatively easy and safe way to raise the tissues, thereby avoiding sharp instruments which could penetrate into the pelvic cavity.

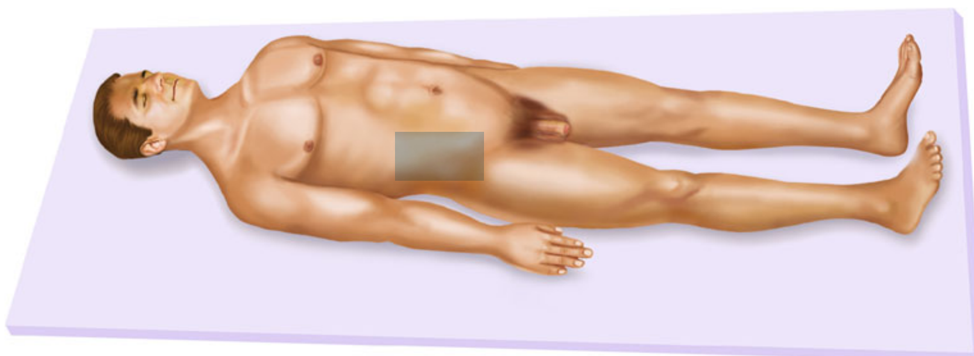

Fig. 18.14 Initial patient position and orientation

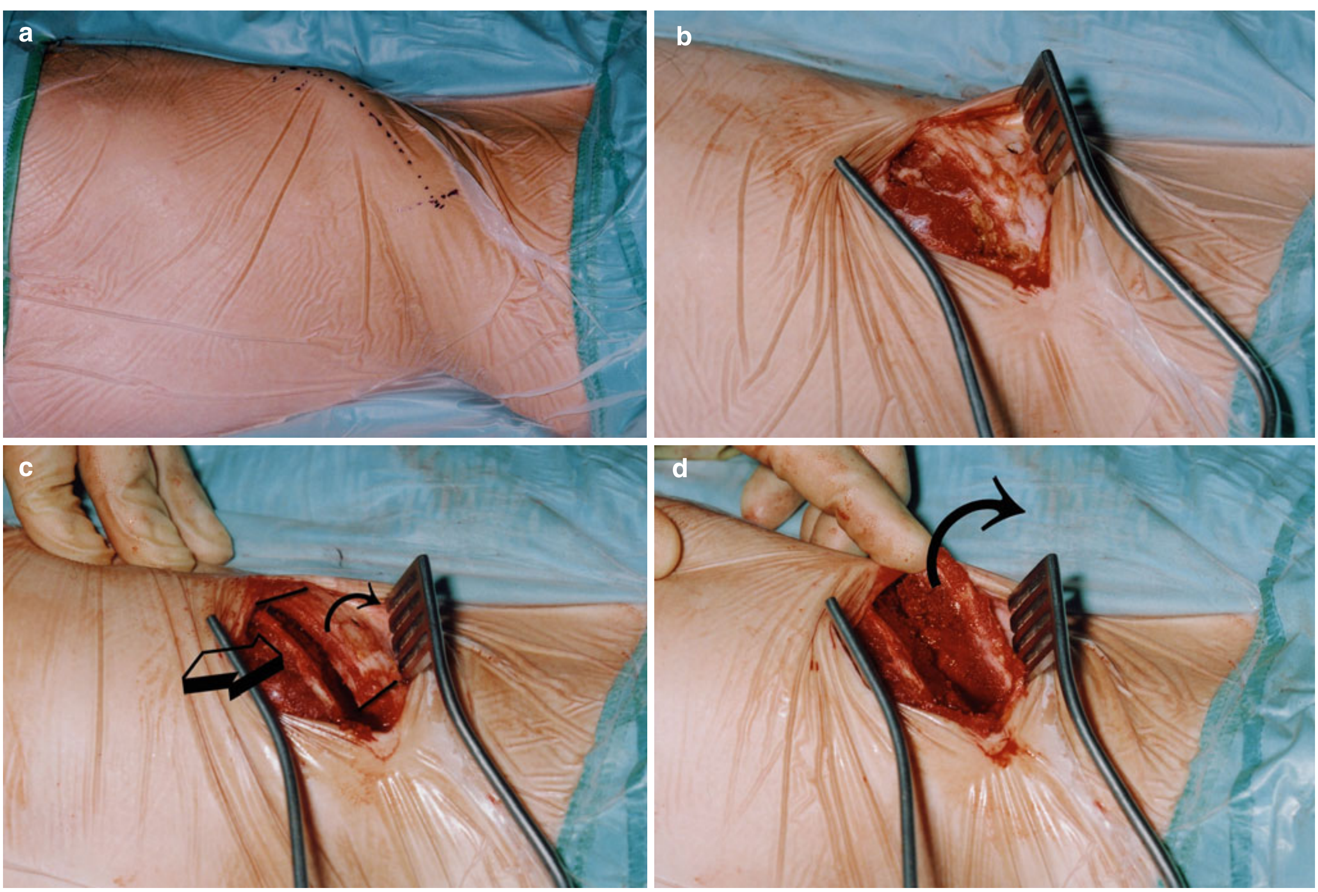

Fig. 18.15 (**a**–**d**) Skin marking, initial dissection and osteotomy of the crest, which is hinged medially (“coffin lid”). The *arrows* indicate the rotation of the crest

Using a right-angled saw, osteotome or drill, bone cuts are then made though the cortical bone of the inner table, defining the graft margins. Depending on the size of the graft, curvature of the pelvis and patient's body habitus, the deepest marginal cut can sometimes be difficult to make. This may require a curved osteotome rather than a saw (a matter of personal preference). Once the peripheral cuts have been made, the cortical bone is gently separated from the surrounding ilium. This can be done by gently tapping an oseteotome through the cancellous bone, parallel to the cortical surface. The thickness of the bone graft can be varied depending upon how much cancellous bone is taken with the graft. Due to the lesser density of the cancellous bone, resorption of this part of the graft is more unpredictable and compaction of the cancellous bone may help reduce this.

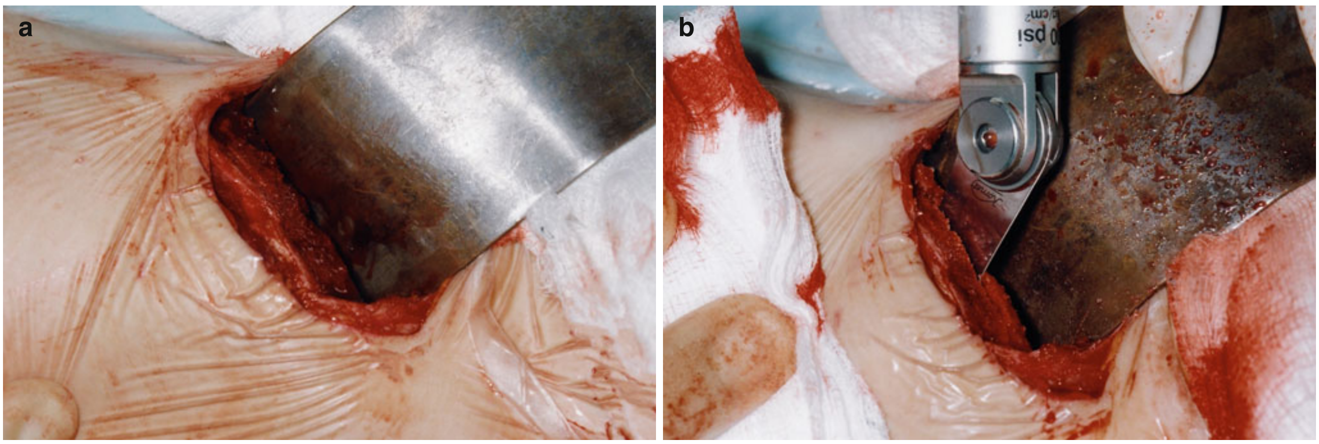

Fig. 18.16 (**a**, **b**) Retraction of periosteum, iliacus and pelvic contents medially, prior to bone cuts with saw and osteotome

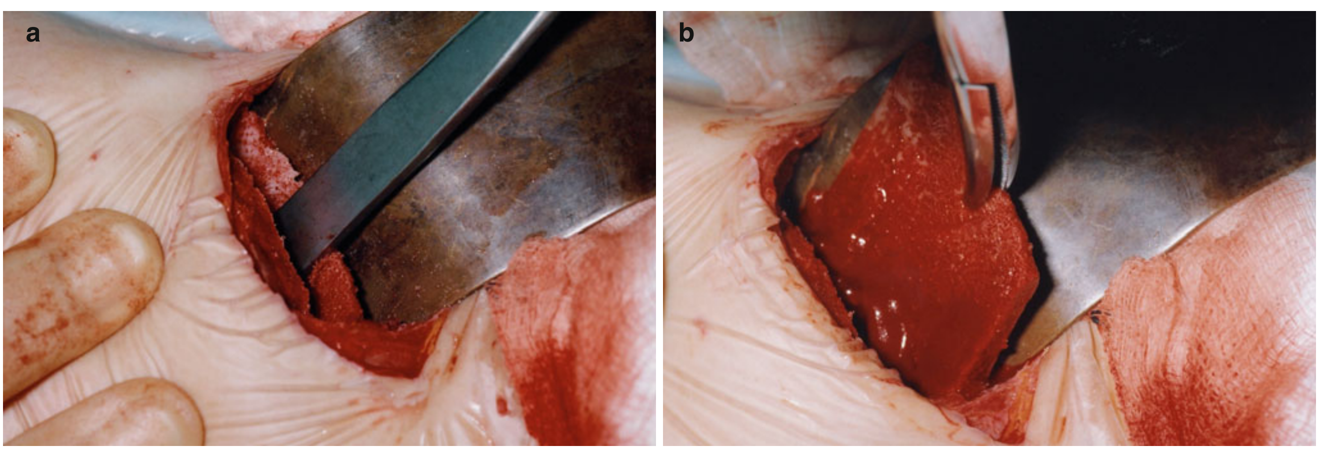

Fig. 18.17 (**a**, **b**) Completion of cuts with an osteotome. Graft is composed of medial (inner) cortical bone of pelvis and adjacent cancellous bone

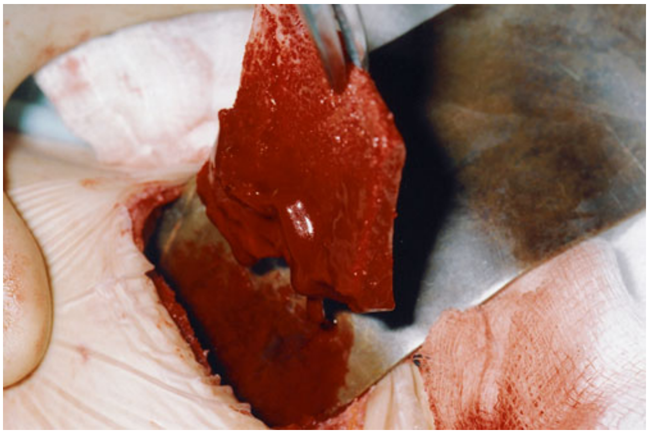

Fig. 18.18 Detachment of free graft

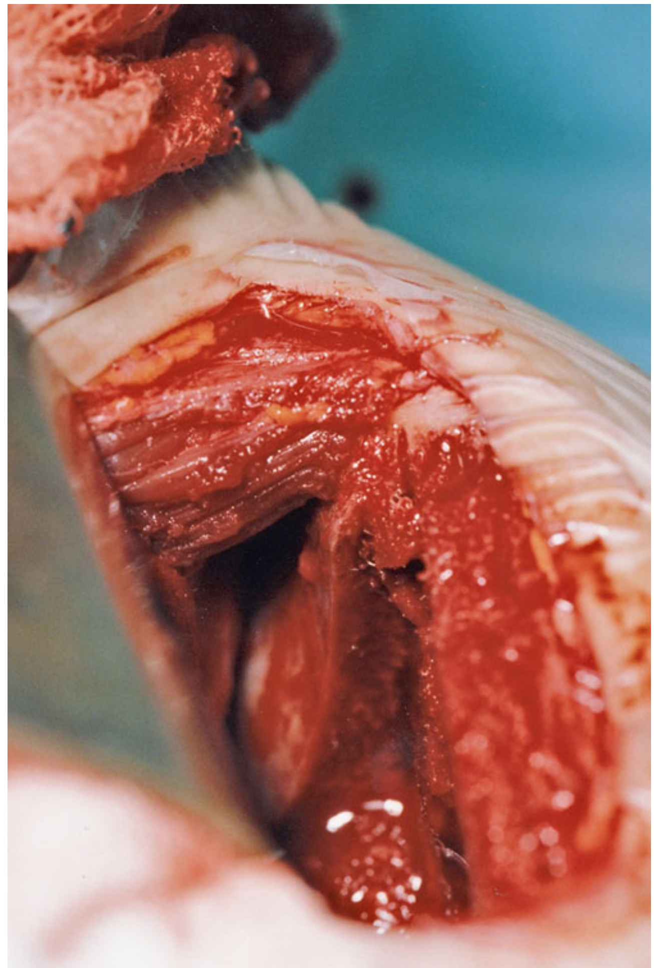

Fig. 18.19 "Patient's eye view" of right iliac crest surgical bed. Contents retracted medially (to the left). Medial cortical and deeper cancellous bone is clearly visible

Following removal of the bone graft, the "coffin lid" is returned to its original position. The lining pelvic perisoteum covers the bony defect and is supported by pressure from the pelvic contents. The repositioned crest can be secured by either suturing the periosteum to the lateral soft tissues or by internal fixation. The wounds are then close in layers. An epidural catheter placed along the crest of the bone is a useful way of providing postoperative analgesia.

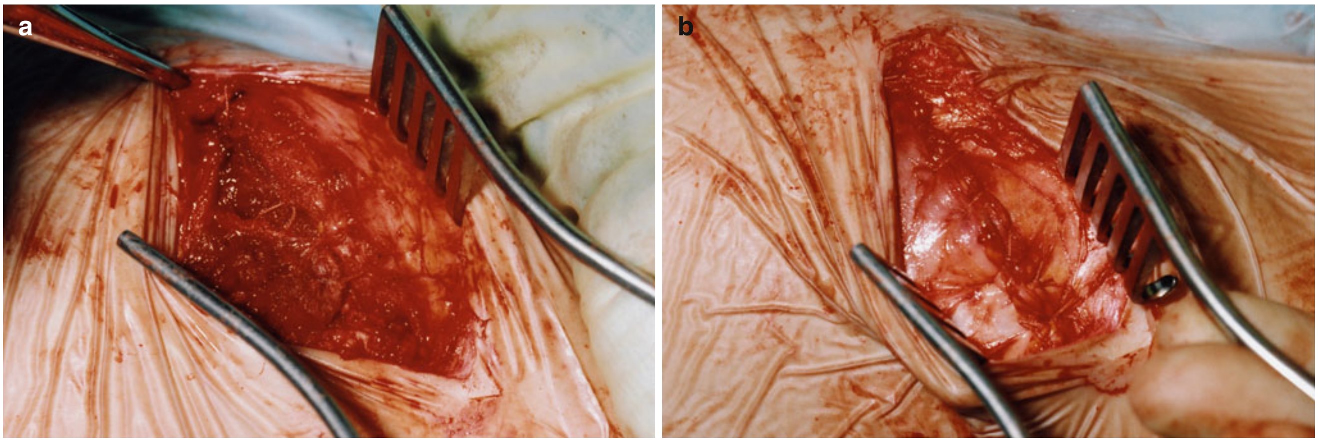

Fig. 18.20 (**a**, **b**) Iliac crest is reattached and wound is closed in layers

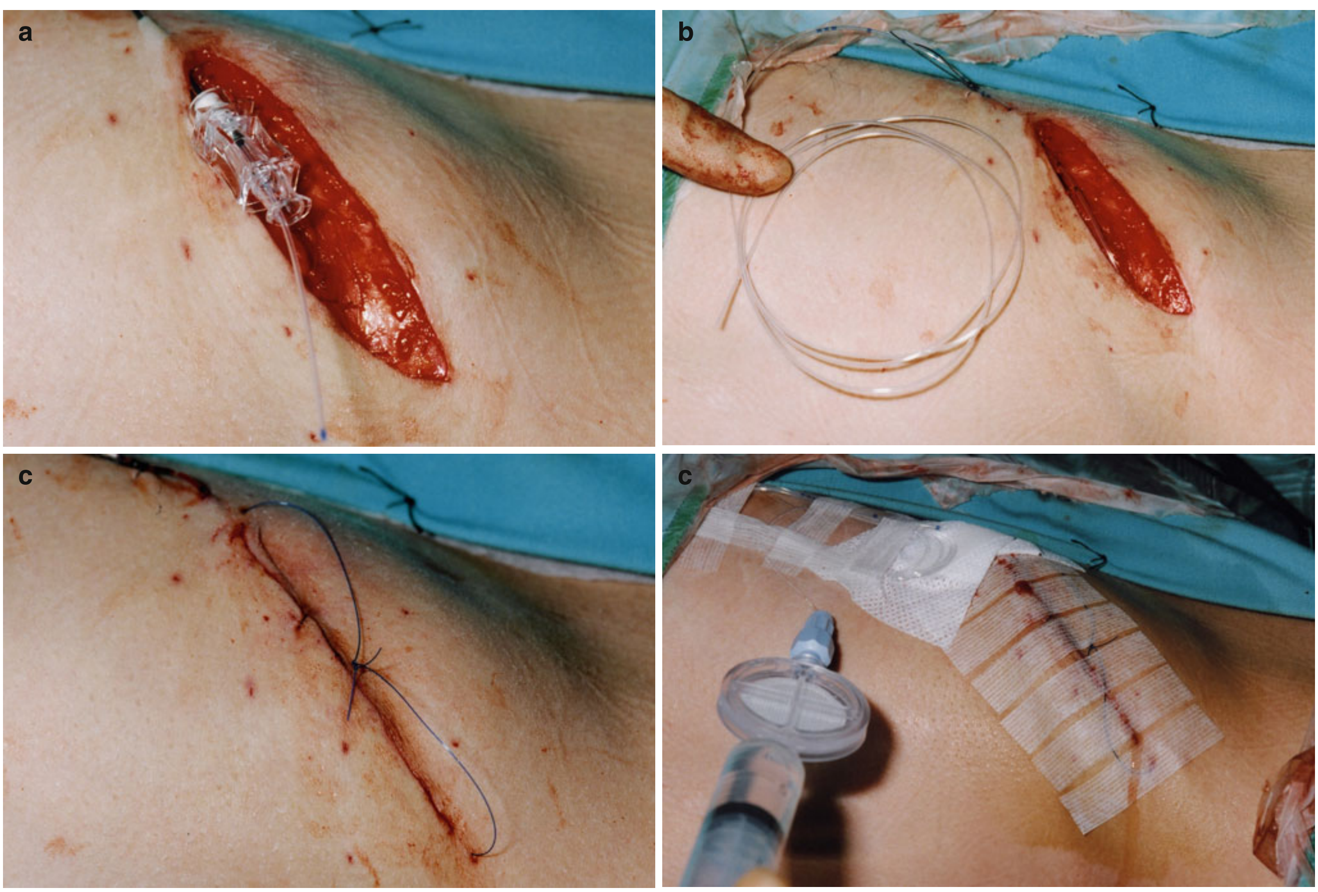

Fig. 18.21 (**a**–**d**) Epidural catheters can be used to allow regular administration of local anaesthesia

18.2.2 Alternative Donor Sites

Alternative donor sites for free bone include the chin, ascending mandibular ramus, rib and calvarial bone. The techniques for harvesting genial and calvarial bone follow the same principles as for iliac bone—the periphery of the graft is defined and an osteotome is used to separate the cortical bone from the underlying cancellous bone.

Calvarial bone can be harvested as a separate procedure, but carries obvious risk and may be limited in size. However, splitting the inner cortical bone away from the outer table following craniotomy can provide a large amount of bone with no added risk. Genial bone is compact but small in volume. It is accessed in the same way as a symphyseal/parasymphyseal fracture with the same risks and precautions. The resulting defect can be filled with a suitable bone source if required. Although an uncommon site, the ascending ramus can provide a small block of compact bone. If the posterior mandible is edentulous, this site can also be used.

Fig. 18.22 Corticocancellous bone and template

18.2.3 Calvarial Graft

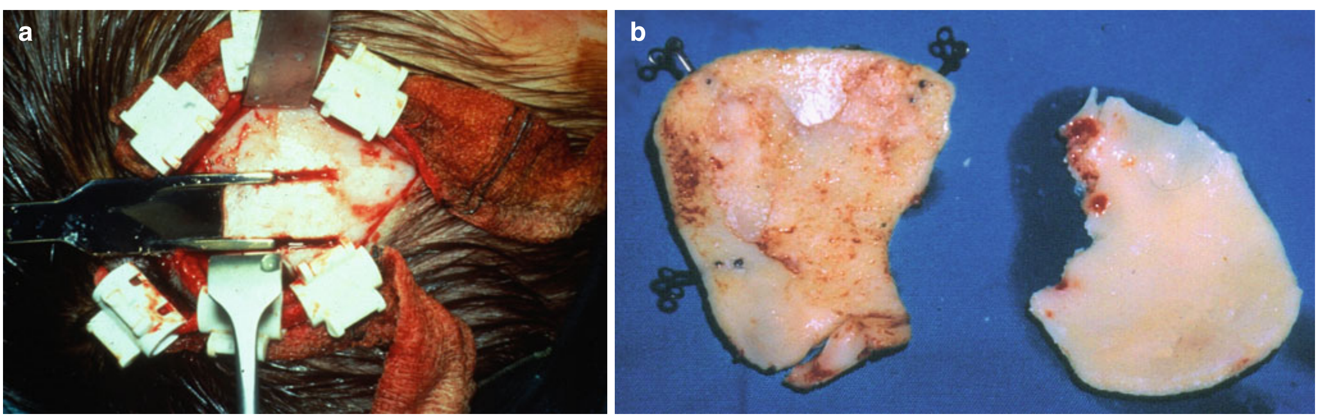

Fig. 18.23 (**a**, **b**) Calvarial graft: harvesting of outer cortical bone versus splitting of a craniotomy

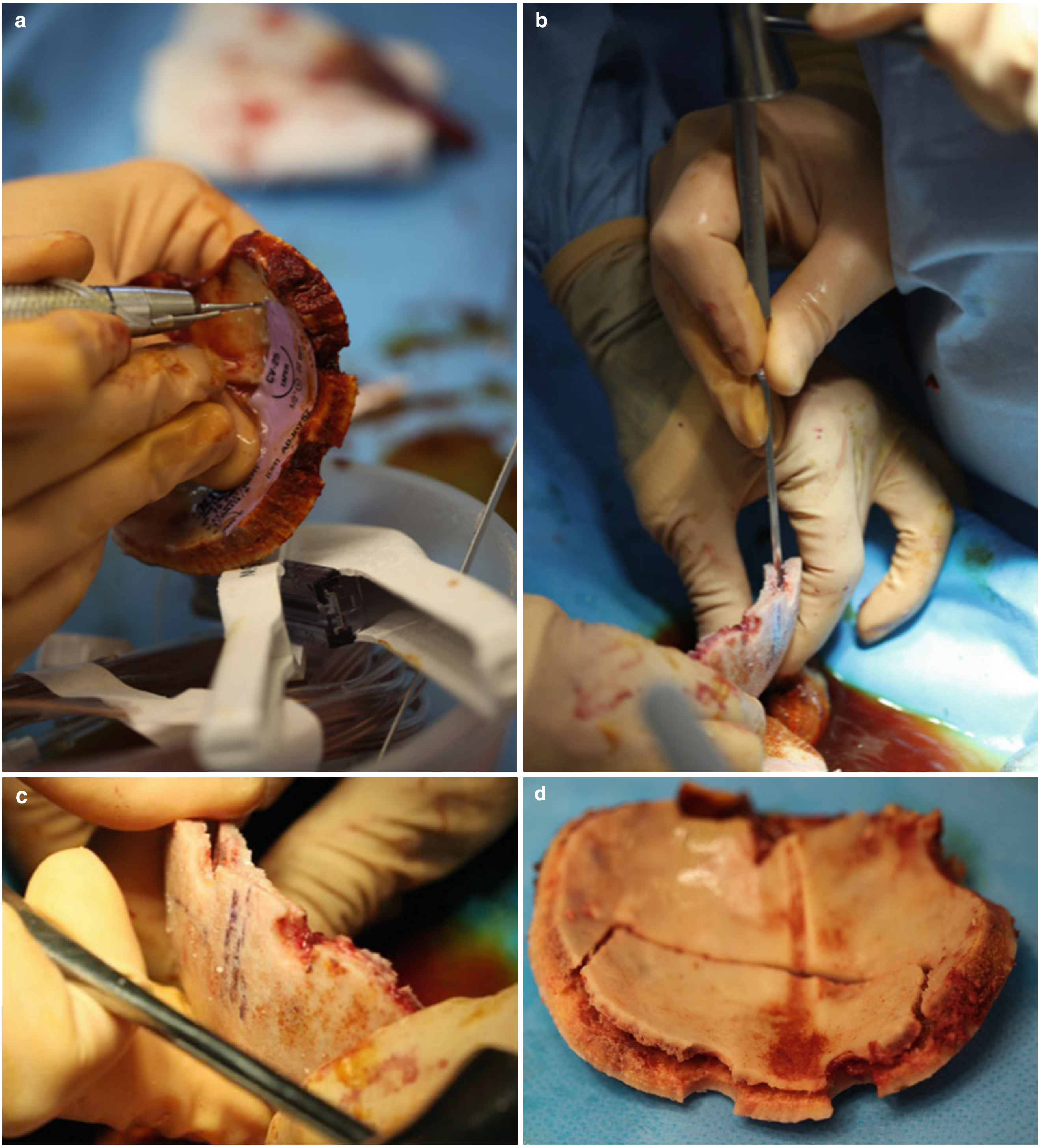

Fig. 18.24 (**a**–**e**) Splitting a craniotomy. This takes time and patience. Various techniques exist, but the principle is to gently cut into the cancellous bone (with a burr, saw or osteotome), gradually separating the two cortical plates. Can be a little tricky with large grafts due to the natural curvature of the bone

Fig. 18.24 (continued)

Fig. 18.25 (**a**–**c**) Primary bone grafting to nose during repair of craniofacial trauma

18.2.4 Genial Graft

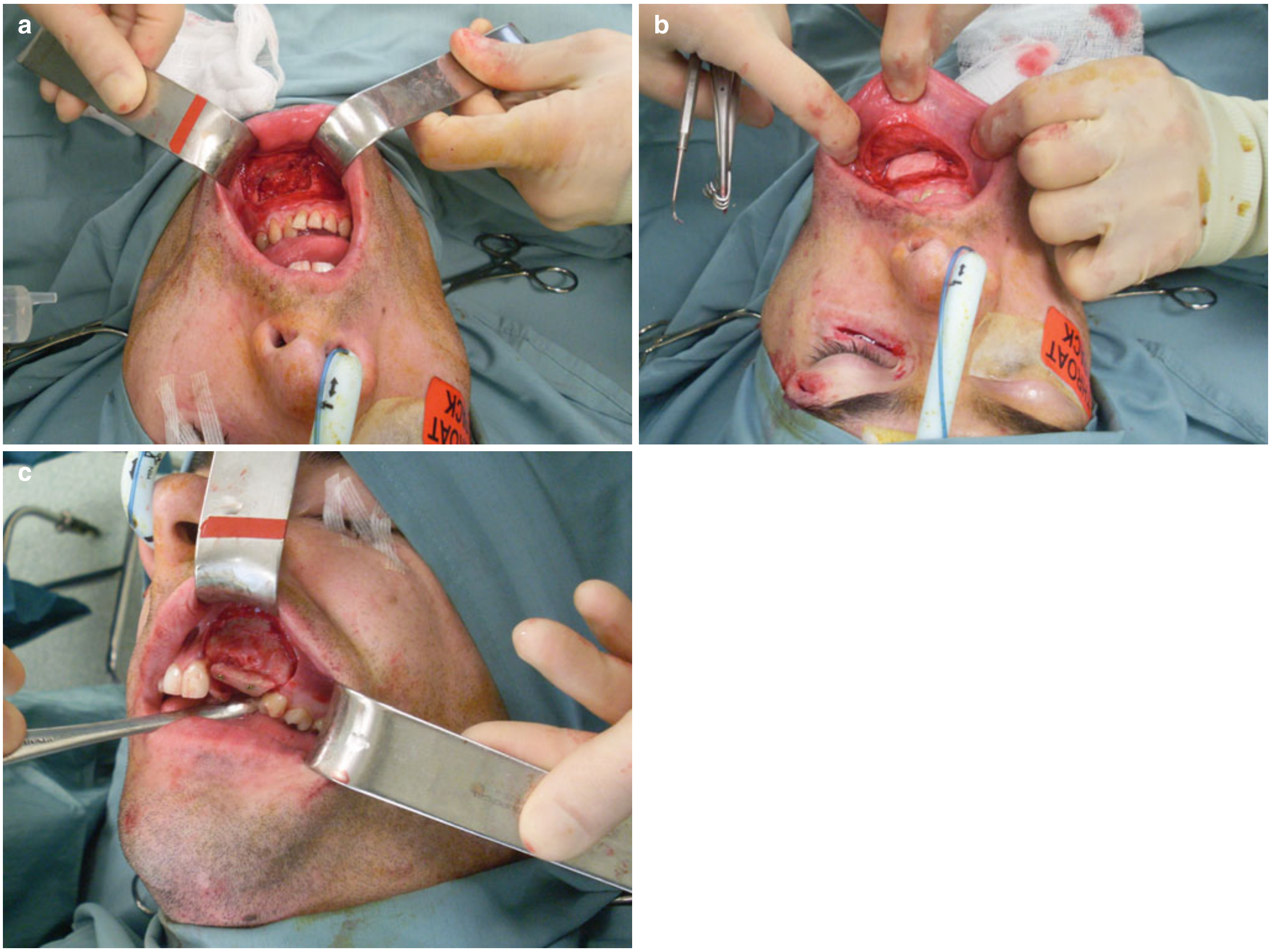

Fig. 18.26 (**a**–**c**) Harvesting of the outer cortical bone of the symphyseal region. Care is required not to damage the roots of neighbouring teeth. This graft has been used to augment the dentoalveolar bone prior to implants. The donor defect can be left to heal or filled with an artificial bone source

18.2.5 Ramus and Coronoid Graft

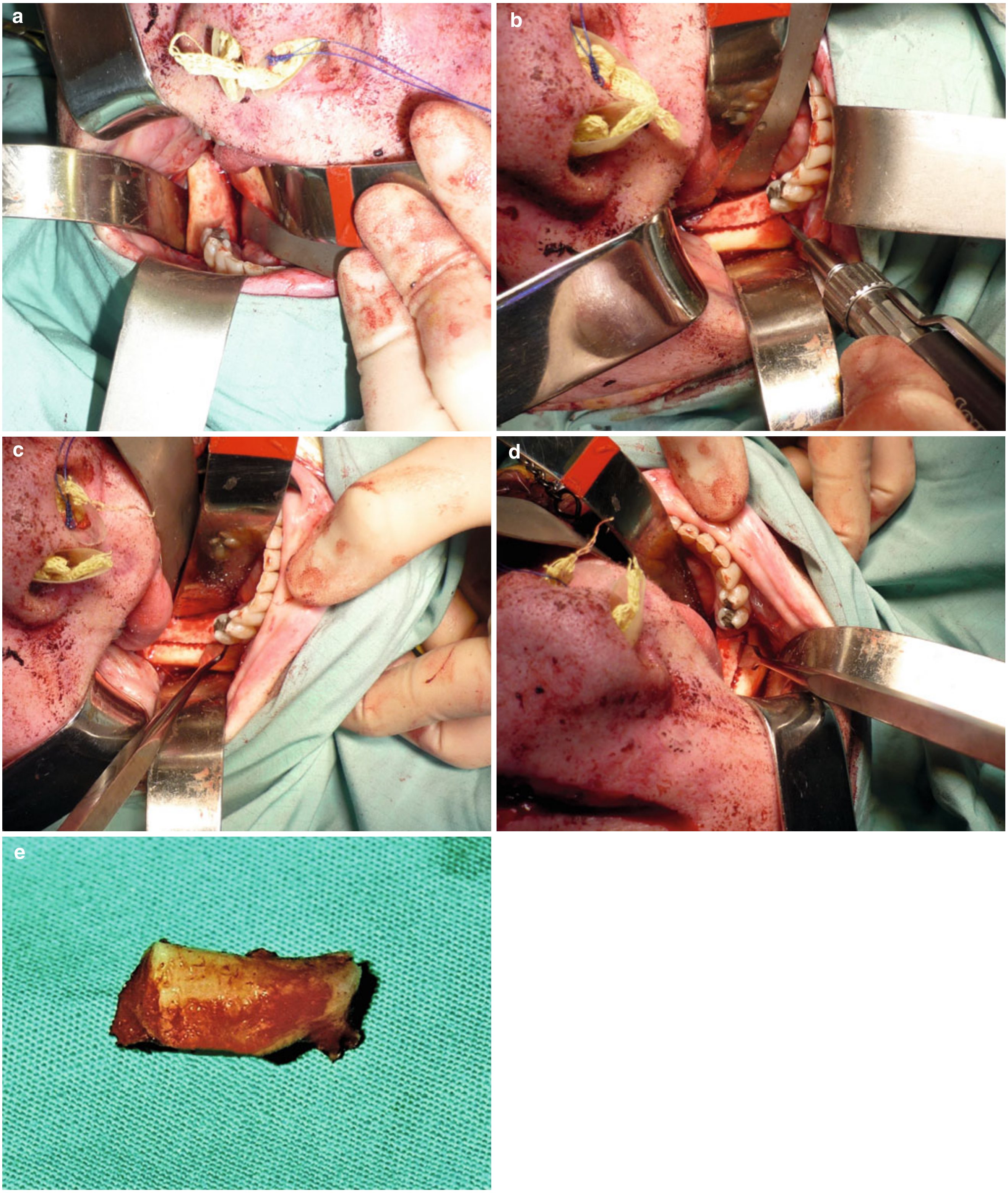

Fig. 18.27 (**a**–**e**) Harvesting of a corticocancellous block from the right posterior molar/ramus region

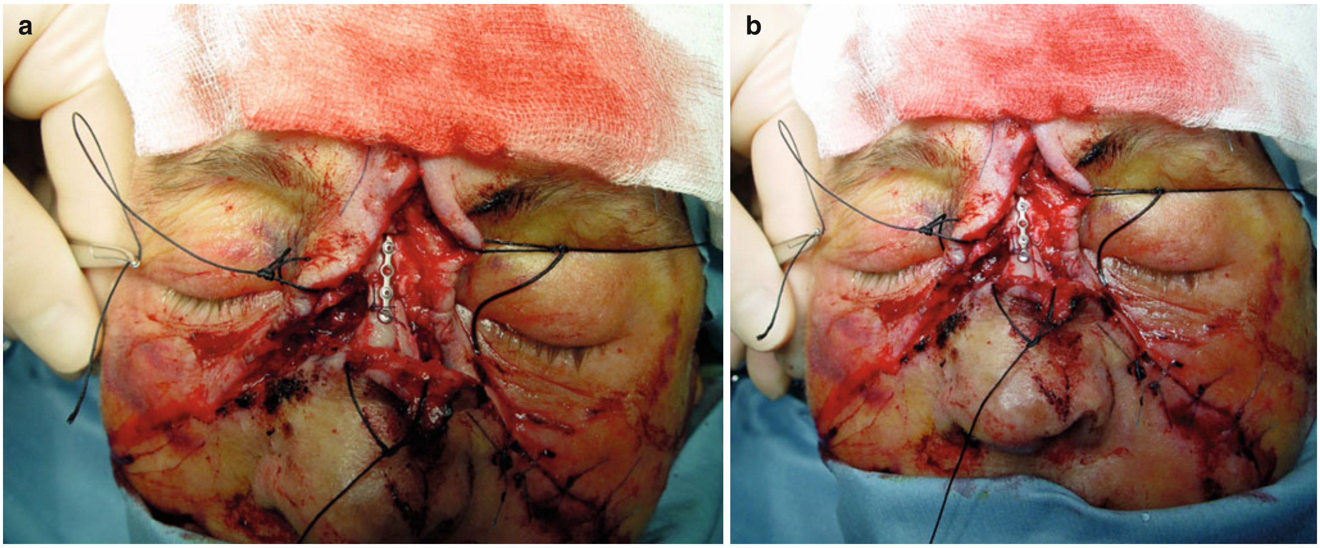

Fig. 18.28 (**a**, **b**) Ramus graft used for nasal augmentation

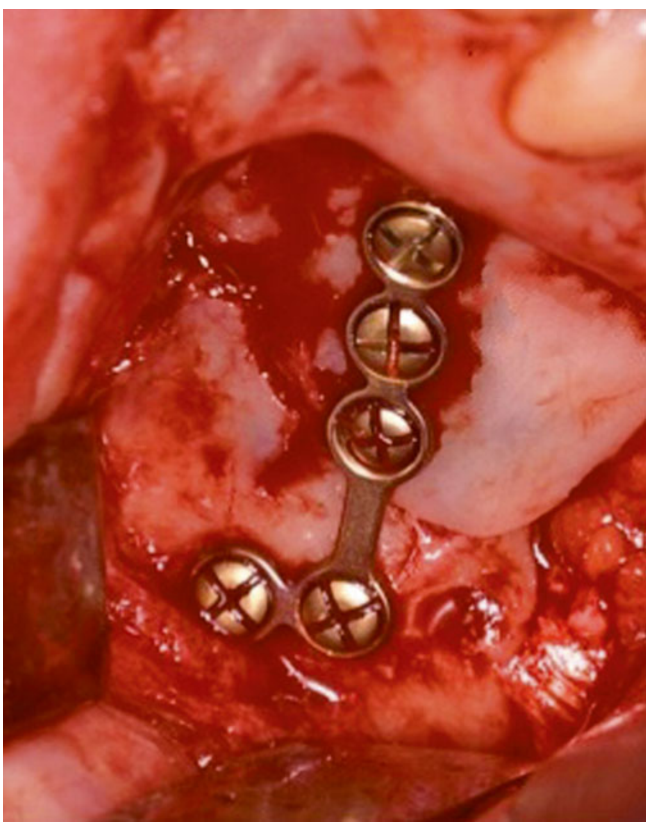

Fig. 18.29 Coronoid process used to graft the left zygomatic buttress

18.3 Costochondral Grafts

Rib can provide both bone and cartilage, either separately or as a single graft. Bone may be used in the repair of fractures of the edentulous mandible. This is reported to provide osteogenic material, as well as supporting the fracture. However, the cortical bone is not particularly thick or strong, especially in the elderly, and internal fixation is still required.

Elsewhere, cartilage is a versatile choice of material, so long as it is used in appropriate circumstances. It is biocompatible and easy to shape (carving costochondral cartilage is a bit like carving a candle). However it should not be used in load-bearing reconstructions and it can gradually return to its original shape if placed under tension. This is due to cartilage's elastic "memory." Nasal tip reconstructions using conchal (pinna) cartilage require careful attention because of this. If bulk is required rib cartilage provides the greatest volume.

Cartilage grafts are therefore very useful as surface onlays, such as in augmentation of the nose, cheeks, mandible or other sites. Costochondral graft (i.e., rib bone and cartilage) is the preferred material of choice in temporomandibular joint (TMJ) reconstruction for many surgeons.

Harvesting a costochondral graft should be straightforward in most cases, so long as there has not been a history of significant chest trauma (notably fractures of the ribs or sternum). A number of sites are available. More cartilage is available in the lower ribs and this maybe preferable in total ear reconstruction. In the examples shown, the cartilage was harvested from the fifth rib.

A full-thickness incision placed in the submammary fold helps to hide the scar. Blunt dissection is then used to identify the rib. The overlying muscles are gently dissected away and a periosteal/perichondrial incision is made along the length of the cartilage and rib. The periosteum and perichondrium are then carefully elevated off the outer surface before extending around and along the deep surface of the rib. This completely strips the desired segment prior to division. Although rib "strippers" are available, elevating

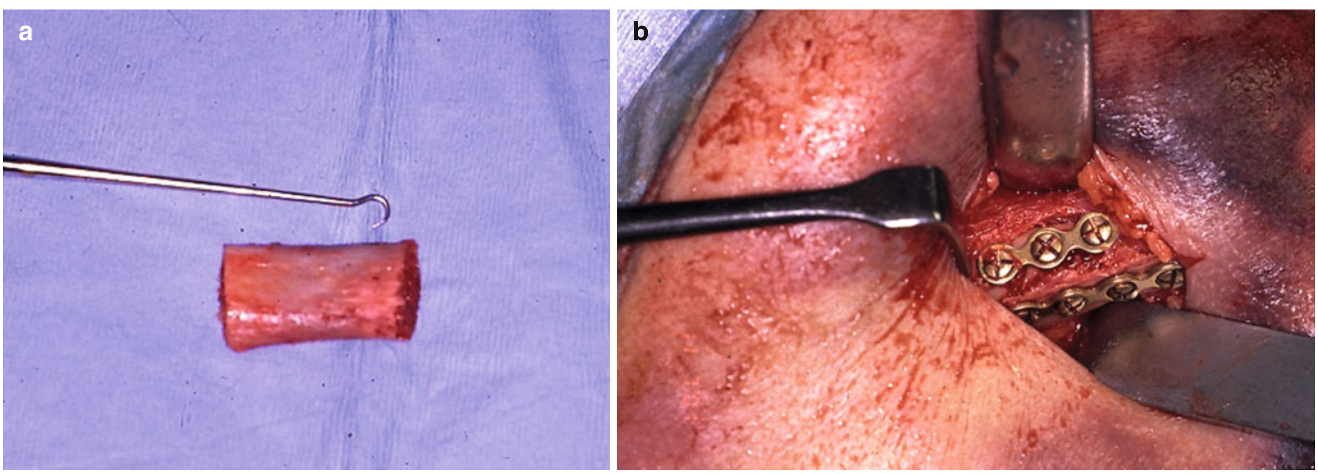

Fig. 18.30 (**a**, **b**) Segment of rib, split lengthwise and used as a graft in repair of atrophic mandible

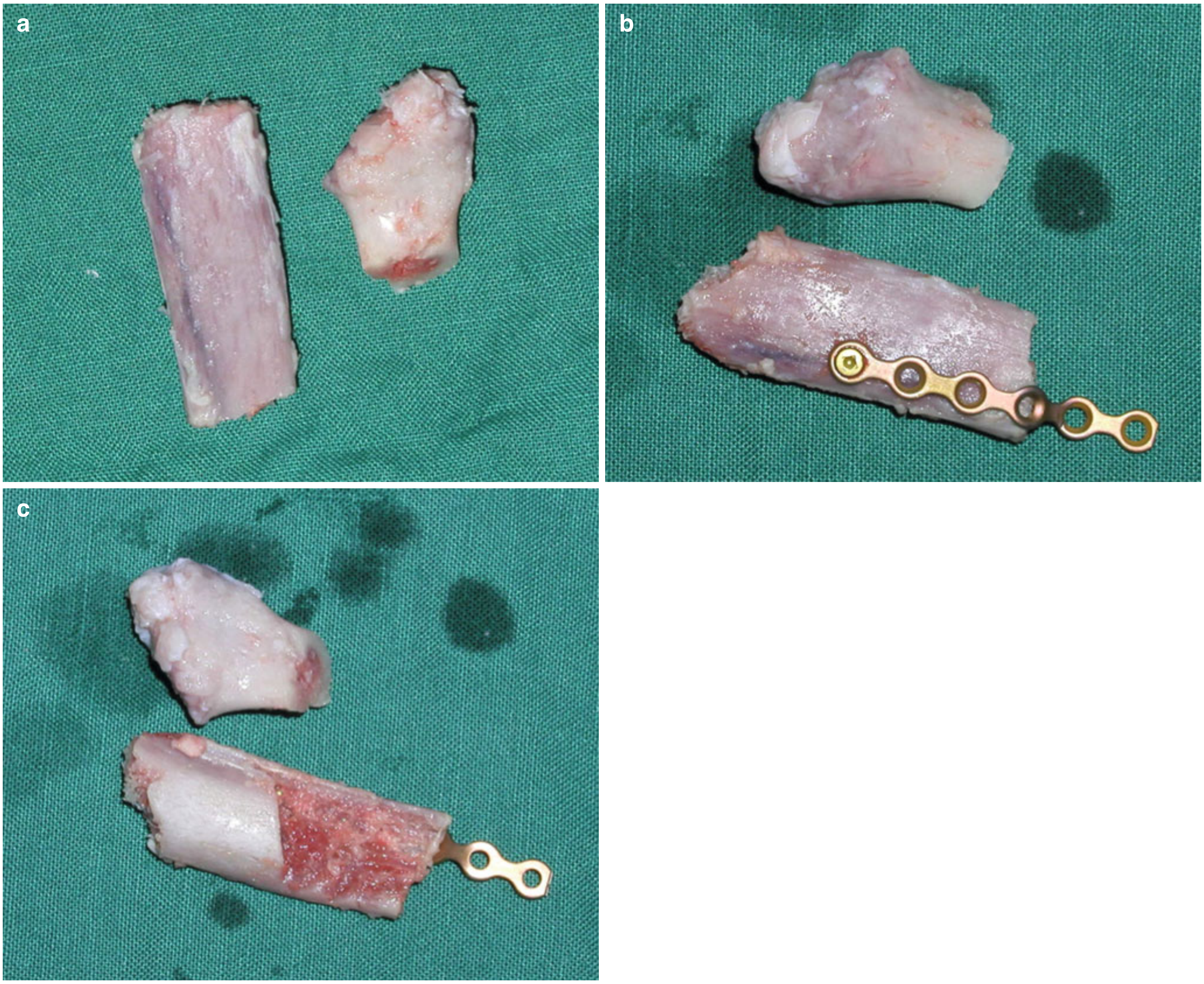

Fig. 18.31 (**a**–**c**) Costochondral graft used in TMJ reconstruction. Graft compared to excised condylar head (ankylosis), prior to contouring

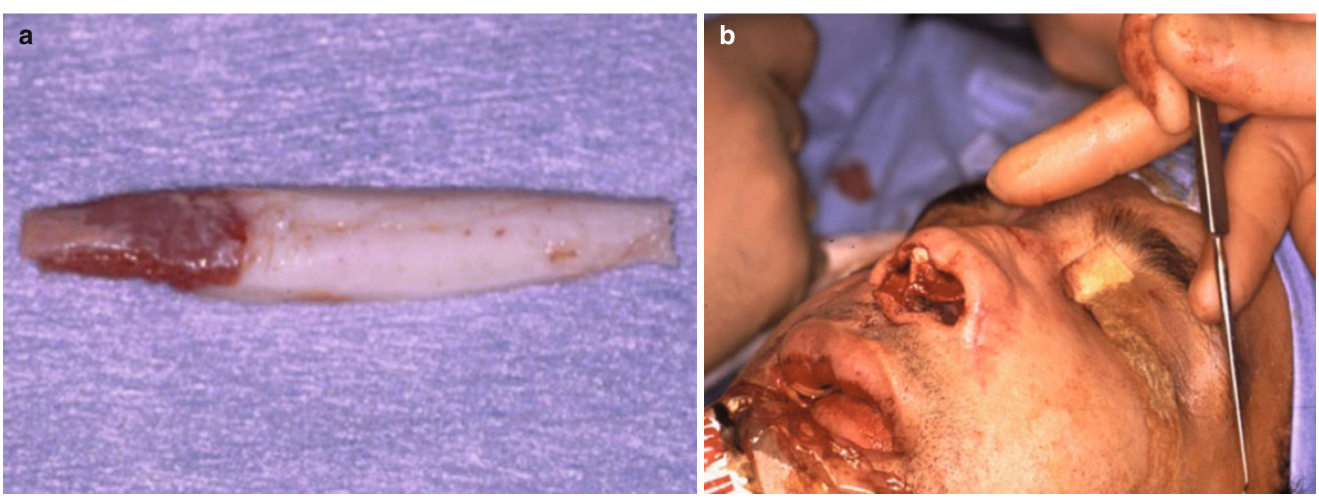

Fig. 18.32 (**a**, **b**) Costochondral graft used in nasal augmentation. Graft is mostly cartilage (pale coloured)

Fig. 18.33 Postoperative appearance

the periosteum and attached muscles can simply begin using a conventional periosteal elevator and flat metal retractors.

The dimensions of the grafts are determined and marked. If just cartilage is required it is carefully incised with a scalpel throughout its entire thickness at both ends and the piece removed. Needless to say, protection of the underlying lung and pleura is essential. A suitable metallic retractor should do this.

If bone is required as well as cartilage, the initial dissection proceeds as described. However, the periosteal and perichondreal attachments at the junction of the cartilage and bone are maintained to leave a cuff of tissue around the junction. This helps prevent separation between the two and may aid in continued growth of the graft, a well-documented phenomenon. Medially, the cartilage is easily incised, but laterally the bone will need a drill, saw or bone cutters.

Following removal of the graft some surgeons pour sterile saline into the surgical bed and ask the anaesthetist to perform a Valsalva manoeuvre on the patient. This should help identify any air leaks through pleural perforations. If these are present a chest drain should be inserted after closure. The wound is then closed in layers.

Case 1

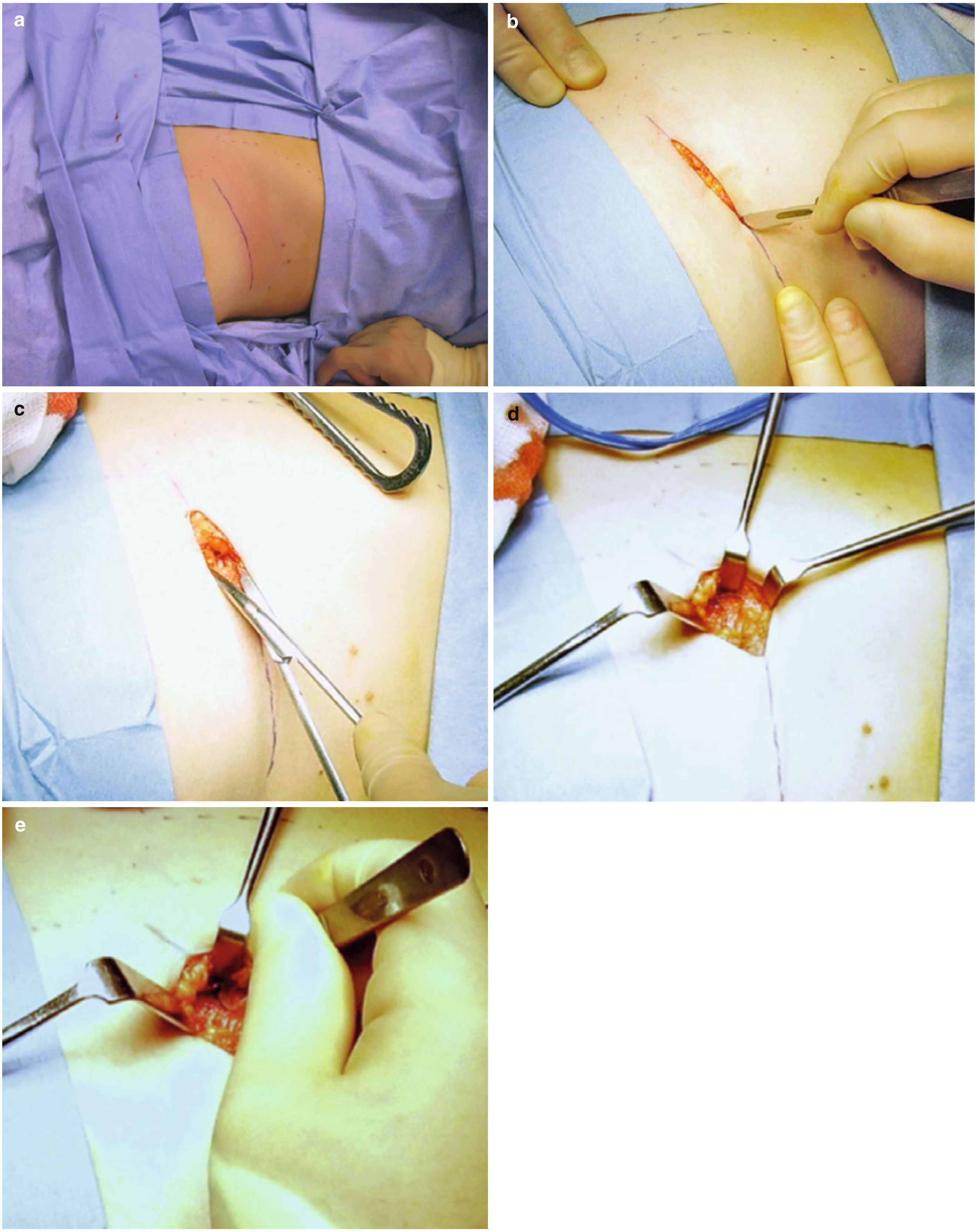

Fig. 18.34 (**a–e**) Harvesting of right fifth costochondral graft. (Patient's head is to the left). Initial skin markings, incision and dissection to expose the rib

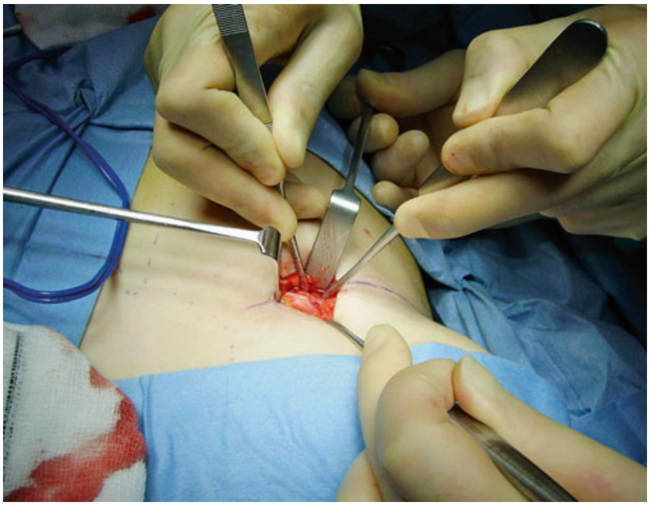

Fig. 18.35 "Patient's-eye view." Sternum is to left

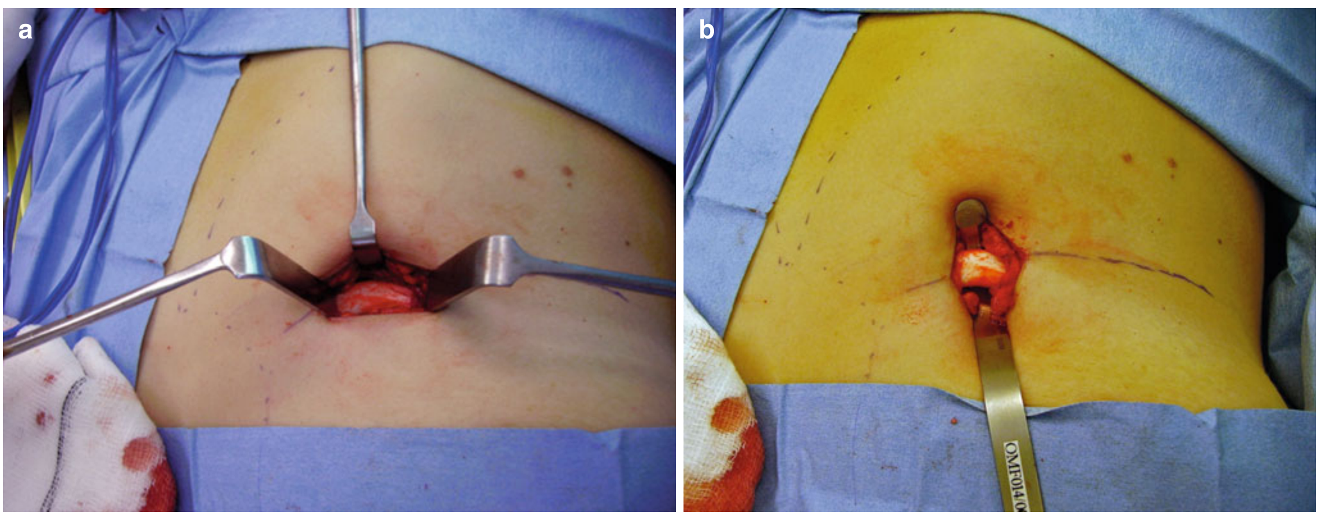

Fig. 18.36 (**a**, **b**) View of isolated fifth right rib following subperiosteal/subperichondral dissection

Case 2

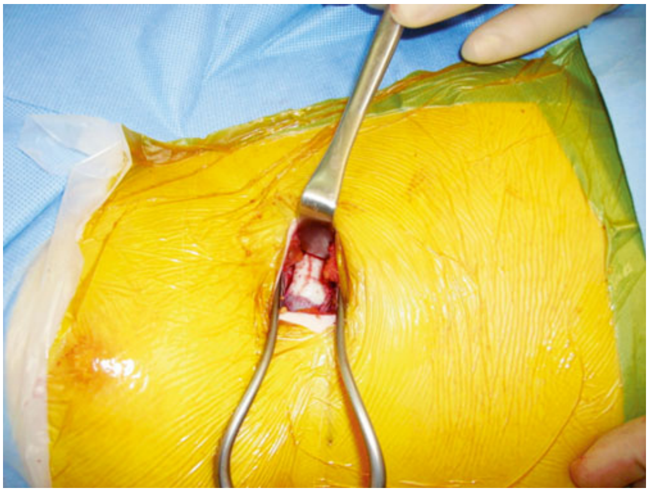

Fig. 18.37 Exposure of fifth rib at the costochondral junction (cartilage is pale, bone is darker). Patient's head is to the left

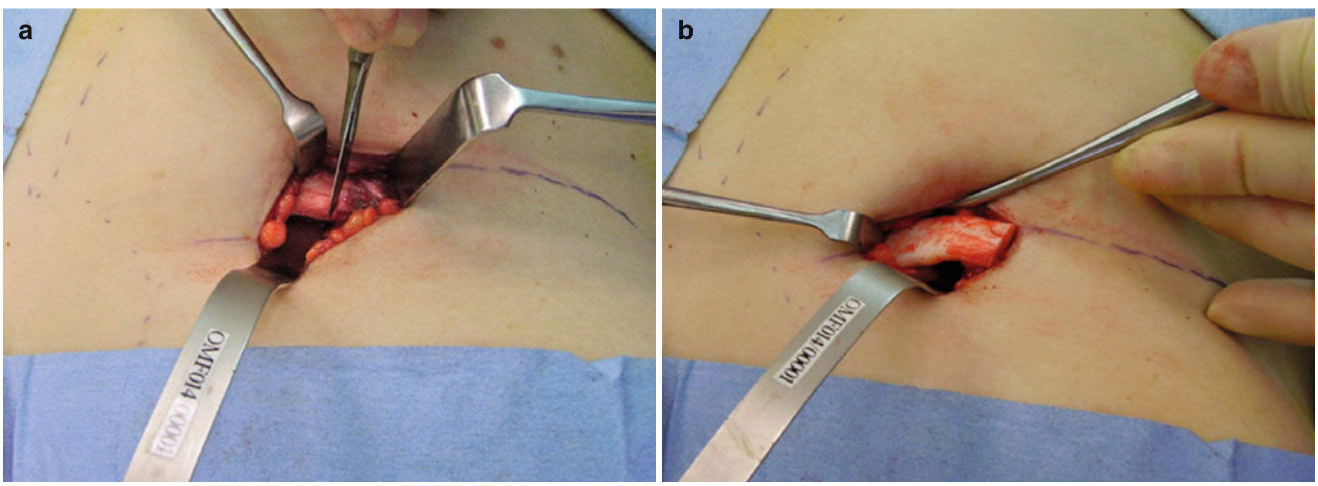

Fig. 18.38 (**a**, **b**) "Patient's-eye view" with sternum on the left. Following isolation of the rib the graft is measured and cut (lateral cut shown)

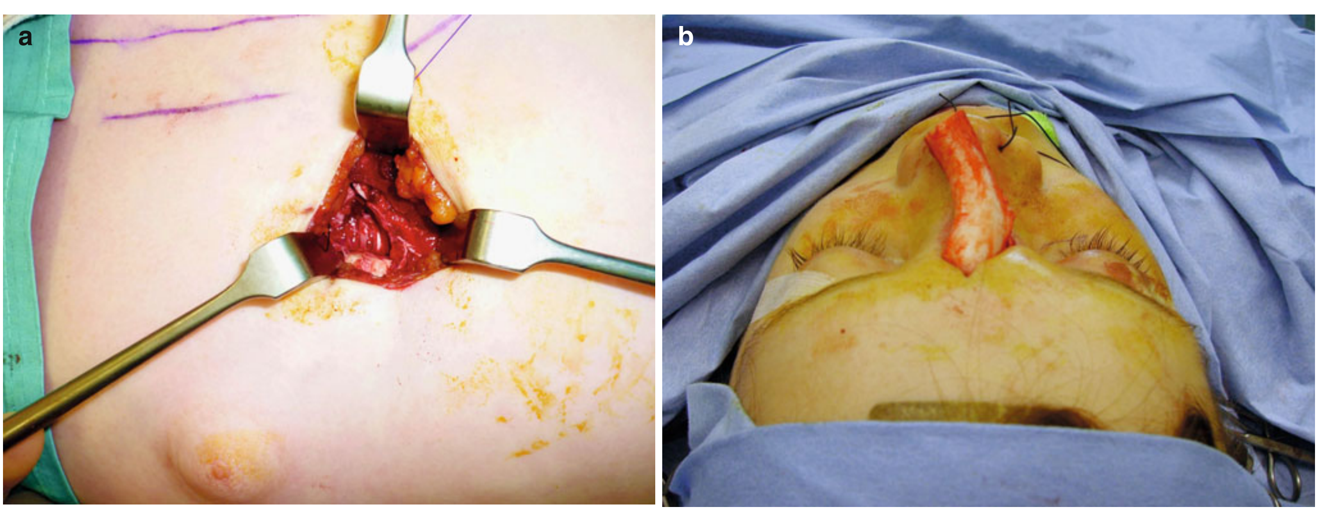

Fig. 18.39 (**a**, **b**) Donor bed and initial sizing of the graft

Case 3: Harvesting a Graft Using Rib Strippers

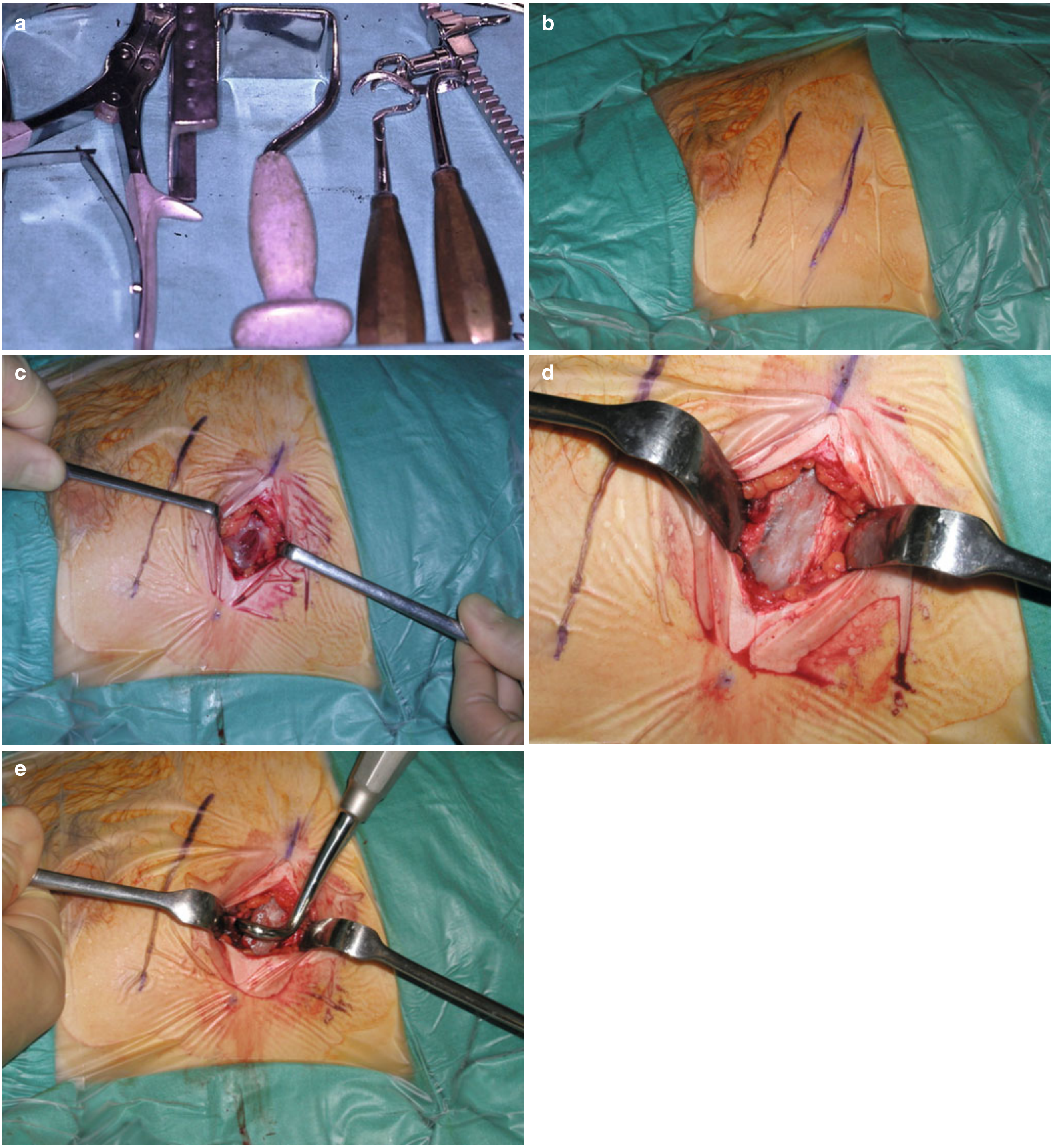

Fig. 18.40 (**a**) Instrumentation. (**b**, **c**) Right fourth and fifth ribs marked out (patient's head is to left). Initial dissection to exposure fifth rib. (**d**, **e**) Periosteum is raised from the outer surface of the rib. The blunt end of the rib stripper is gently passed (rotated) around the rib in the subperiosteal plane

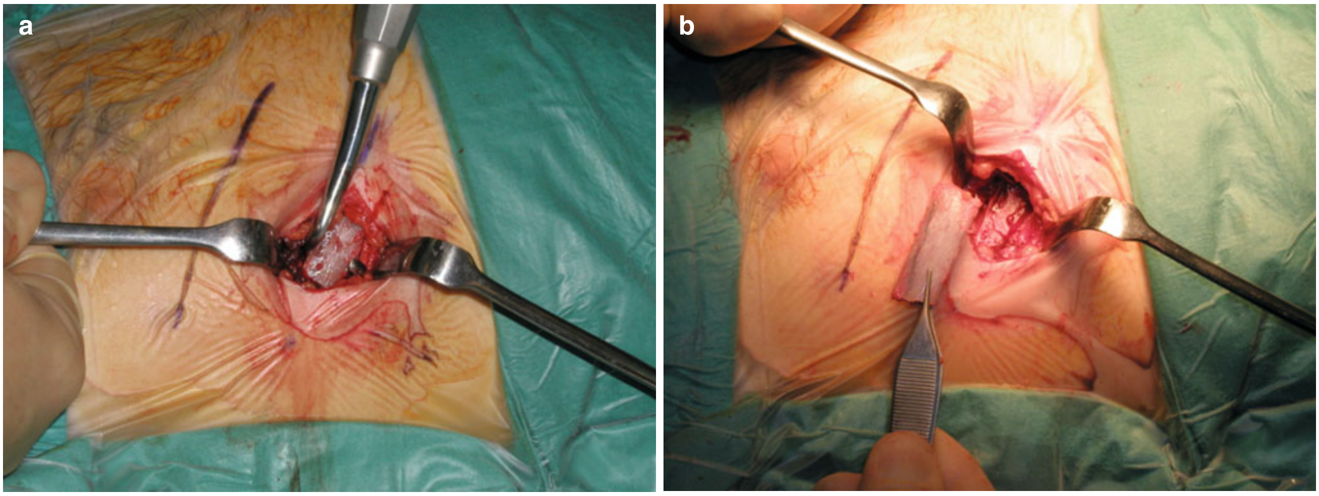

Fig. 18.41 (**a**, **b**) The stripper is then gently passed up and down the length of the rib, thereby elevating the deeper periosteum. This is a “blind” technique. Graft is then raised

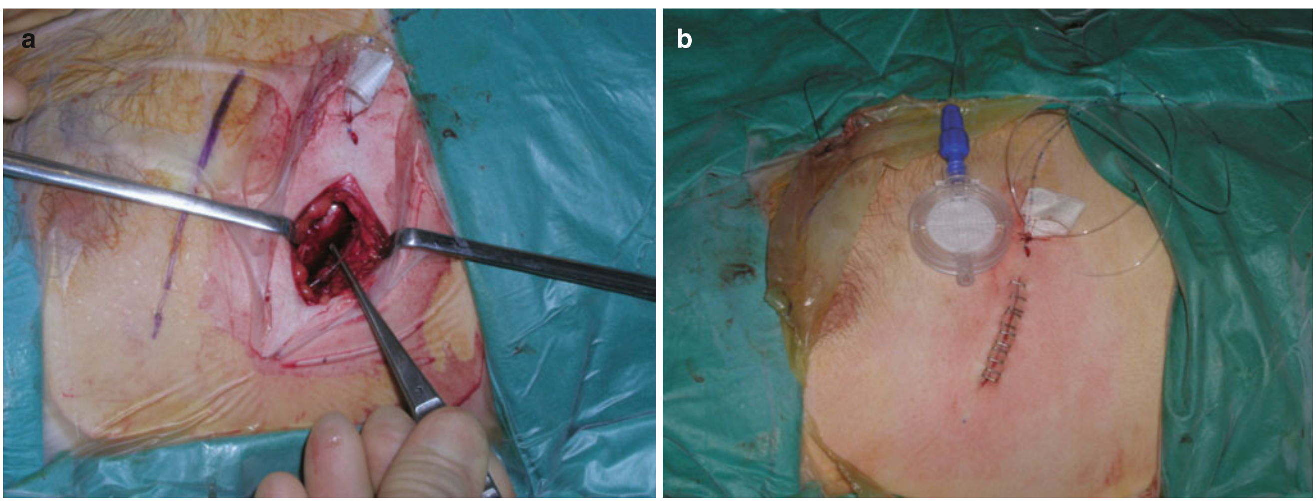

Fig. 18.42 (**a**, **b**) Surgical bed and closure

Fig. 18.43 Costal cartilage graft

18.4 Skin and Dermal Grafts

18.4.1 Full-Thickness Skin Grafts

Skin grafts can be used to provide both temporary and permanent reconstruction of skin defects. Split-thickness skin grafts tend to be used for temporary reconstruction, while full-thickness skin grafts (FTSG, also referred to as Wolfe grafts) can sometimes provide a surprisingly good permanent result. Defects covered by FTSGs contract less than those covered by split thickness grafts. FTSGs are therefore preferable at sites where this would be a major concern (e.g. eyelids). FTSG also give a much better cosmetic result than thinner grafts.

In order to get the best colour match, grafts are harvested from either the face or neck, as the skin here is of similar thickness, quality and vascularity. A number of useful donor sites exist. These include the supraclavicular fossa, preauricular and postauricular skin. Eyelid skin is relatively unique and can be particularly difficult to reconstruct. In some cases the best option is to harvest skin from the opposite eyelids (in those patients who have an excess of skin).

Before harvesting a FTSG, the extent of the defect needs to be fully defined and measured. If there has been a delay in treatment, the wound edges may have contracted, making the defect appear smaller than it actually is. The tissues therefore need to be carefully assessed and mobilised, excising any necrotic tissue. If the recipient site has an irregular-shaped margin, this can either be accepted or further skin removed to define an aesthetic facial unit. However, removing an excessive amount of healthy skin may potentially result in a bigger reconstructive problem if skin graft dies or becomes infected. This is a matter of choice.

The defects shape is then transferred to the donor site and compared to the amount of available skin. This ensures that the donor wound can be closed following removal of the donor skin. If the shape is irregular, it can be extended or rounded to form an overall elliptical or crescentic shape, which will facilitate closure and provide an aesthetic wound.

When raising a FTSG, the aim is to harvest the epithelium and dermis only. Although fat increases the bulk, it can impair successful "take." Harvesting starts by defining the peripheral margin with a full-thickness skin incision. The skin is then gently dissected away from the underlying tissues using a scalpel. Either the skin can be meticulously dissected in the subdermal plane at this stage (which takes longer), or it can be quickly harvested and any attached fat removed by an assistant while the donor site is being closed. Removal of fat can be done by laying the graft (epithelial side down) over one's index finger and using curved, blunt ended scissors to cut away any visible fat. Which approach is taken is a matter of personal choice.

The ideal recipient bed is composed of clean, healthy, vascularised tissues, free from contamination. Meticulous haemostasis is essential to prevent postoperative bleeding under the graft. The graft is then laid over the defect and sutured to the periphery. Interrupted sutures allow serum/oedema, etc., to leak out. An exact shape and size match is not essential—very often grafts will adapt shape to close the defects satisfactorily. However, it is important that the surface area of the graft does approximate to that of the defect, in order to prevent distortion of the adjacent tissues. Some surgeons deliberately perforate the graft to allow serum and blood to escape. Any perforations are best placed prior to fixation of the graft. Perforating a graft once it is secure may result in bleeding from the recipient bed. Depending on the size of the graft, a few central sutures may help prevent formation of dead space. A gentle pressure dressing is then placed over the graft and kept in place for approximately 10 days.

During initial healing, the graft is loosely attached to the recipient site by fibrin and receives oxygen and nutrients by diffusion (a process called plasmatic imbibition). After a few days, capillaries begin to establish a vascular network. Revascularization occurs with further growth of new vessels (neovascularization), this taking approximately 4–7 days. Reinnervation of skin grafts can occur over time but is variable. Sensory return is greater in full-thickness grafts. Similarly, hair follicles may be transferred with a full-thickness graft and growth may resume. Split-thickness grafts are therefore hairless.

Case 1

Fig. 18.44 (**a**–**f**) Harvesting small FTSG using right preauricular skin

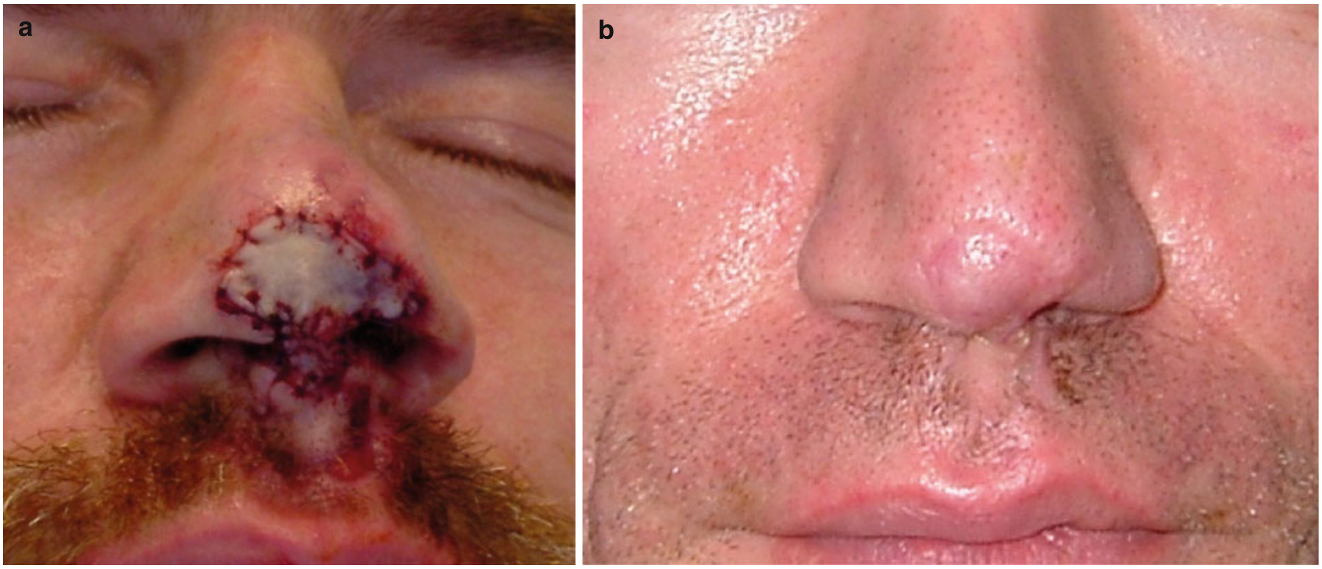

Fig. 18.45 (**a, b**) Graft secured and follow up at 6 months

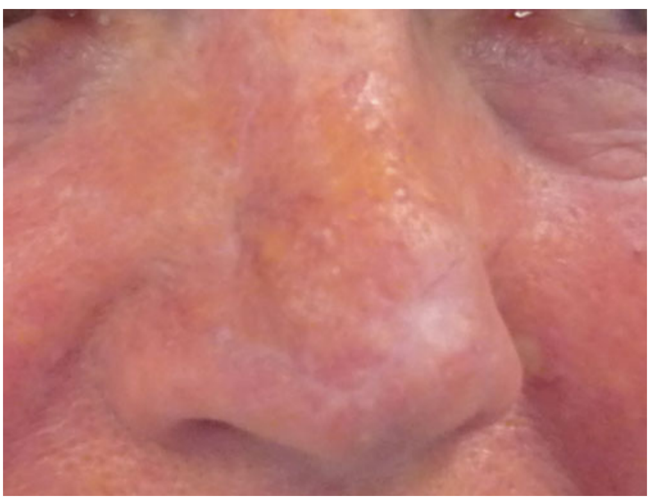

Fig. 18.46 Postoperative appearances 1 year following FTSG to nasal dorsum

Case 2

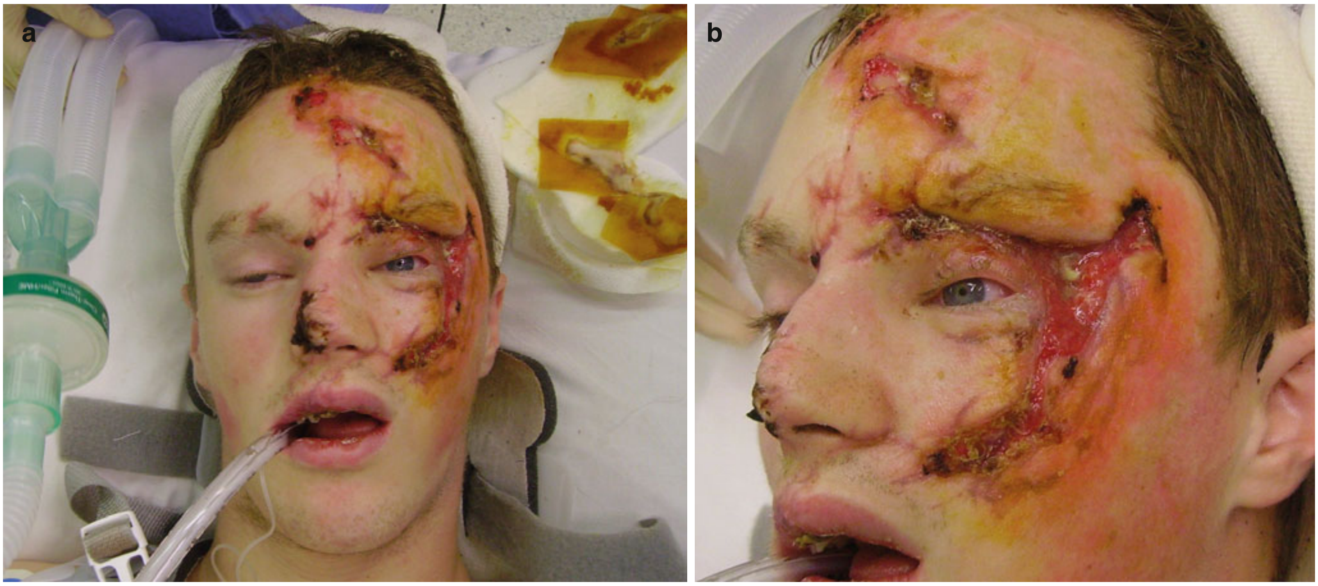

Fig. 18.47 (**a**, **b**) Severe crush injuries to soft tissues (plus craniofacial fractures) following ejection from a vehicle. Delayed presentation. Contraction of the tissues has resulted in distortion of the upper eyelid (potentially vision threatening)

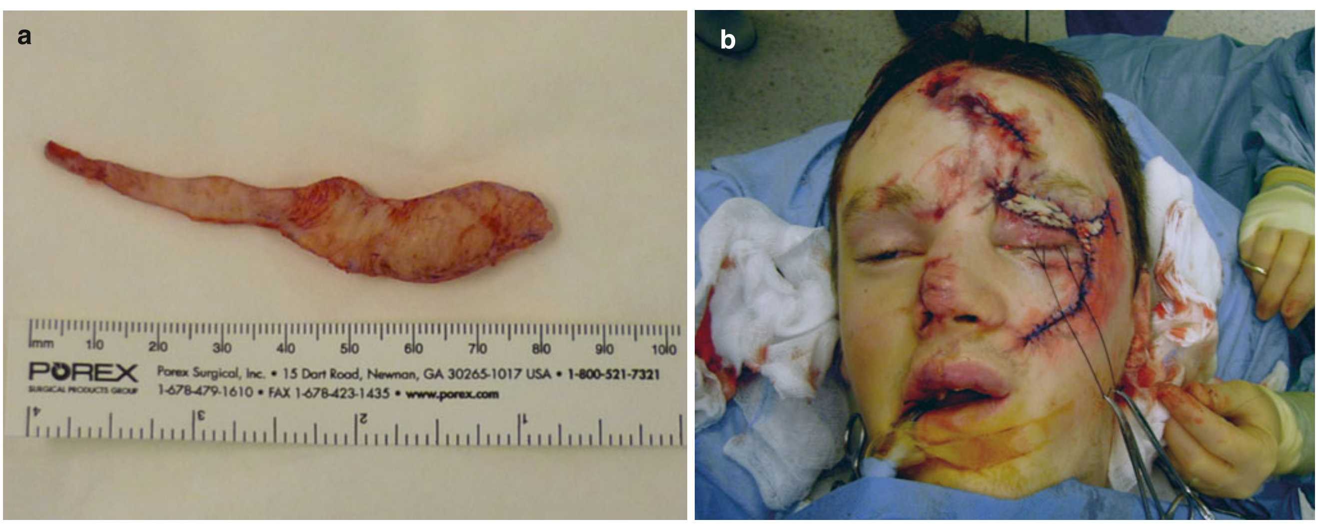

Fig. 18.48 (**a**,**b**) FTSG taken from supraclavicular fossa and used to replace missing skin, allowing closure of the eyelids (note use of traction sutures to minimise further contraction)

Fig. 18.49 (**a**–**c**) Sequential follow-up at 1, 3, and 18 months. A good example of the importance of aftercare and patient motivation

Case 3

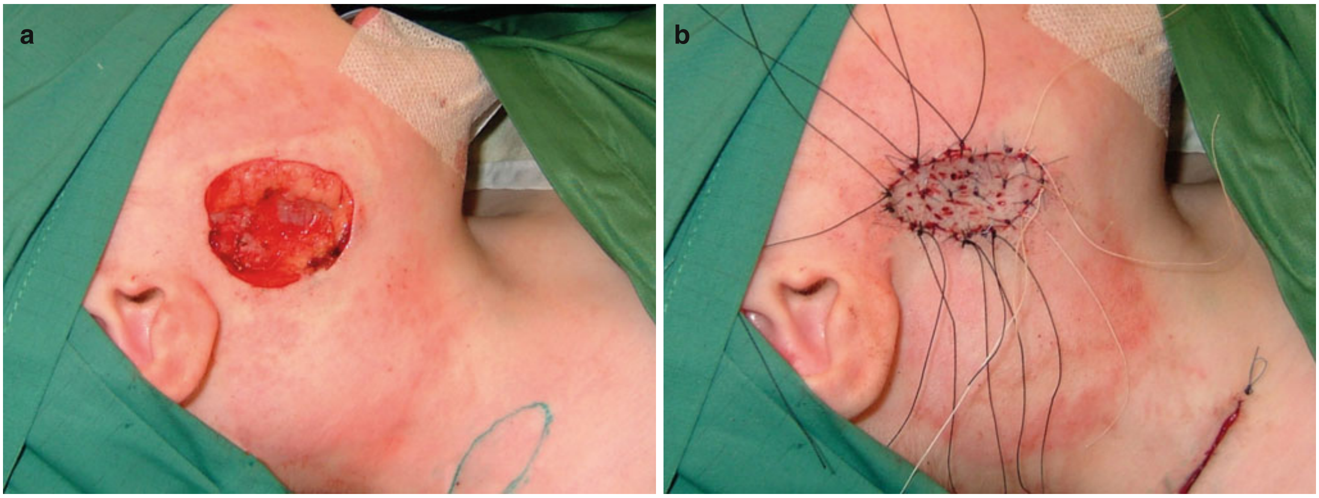

Fig. 18.50 (**a**, **b**) FTSG to right cheek defect following dog bite. Note perforations to allow blood to escape from under the graft

18.4.2 Split-Thickness Skin Graft

Split-thickness skin grafts are commonly harvested from the thigh, buttocks, or abdominal wall. The method of harvesting depends primarily on the size and thickness required to cover the defect. Smaller grafts can be taken using a "pinch graft" technique using a scalpel blade. Larger grafts can be obtained using one of a number of purposely designed blades. Powered dermatomes are now commonly used to harvest split-thickness skin grafts. These have a rapidly oscillating blade that can be set at an adjustable depth and width.

18.4.3 Dermal Grafts

Augmentation or thickening of the soft tissues may be required following high-energy trauma where the tissues have become scarred and atrophic. The skin itself is intact, but the deeper tissues (especially dermis and fat) may have lost volume and are sometimes adherent to the underlying bones. This can be particularly noticeable over bony convexities such as the orbital rims, forehead and nasal bridge, where the skin would normally drape loosely.

Today, a number of synthetic materials are available, but if required a free dermal graft can be harvested. These are often taken from the abdomen using a preexisting scar if present. If there is no preexisting scar, the dermis can be taken from anywhere (although it is best to avoid the right iliac fossa; this may cause diagnostic confusion if the patient develops abdominal pain in the future). Some surgeons prefer a low transverse (Pfannenstiel's) incision to hide the donor scar.

Generally, grafts are raised as an ellipse with a minimal length-to-width ratio of 3:1. This facilitates closure. The

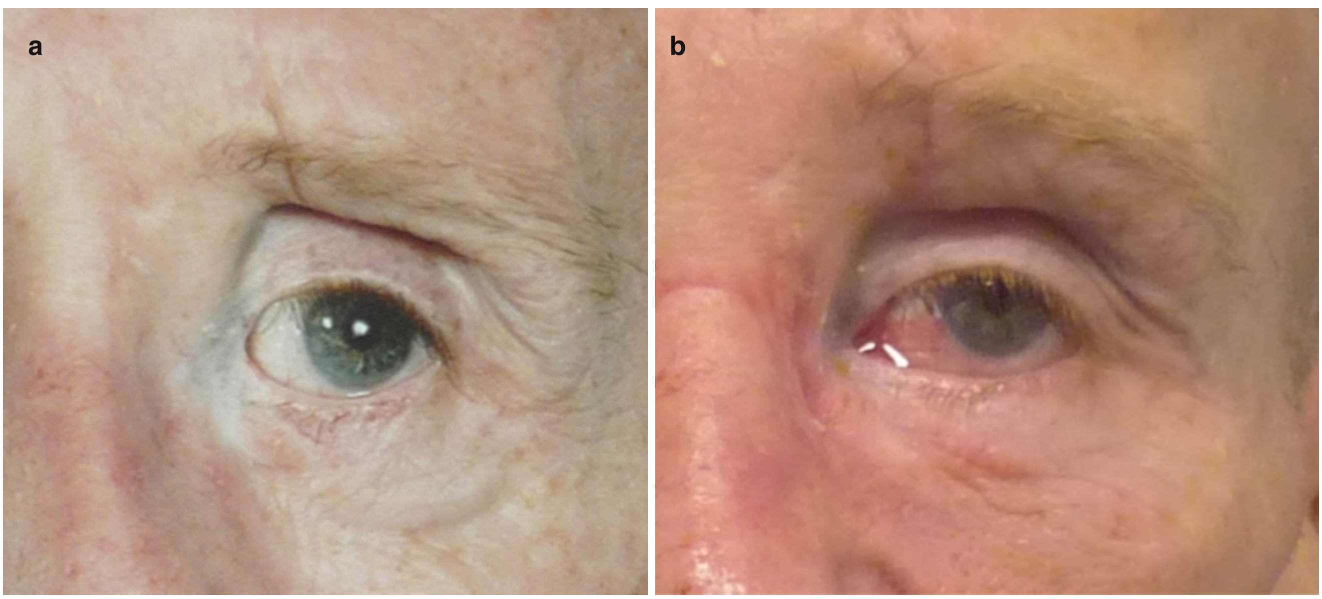

Fig. 18.51 (**a**, **b**) Soft tissue (dermal) augmentation to thin atrophic and scarred skin around left orbit. (Patient is blind in left eye from previous globe injury)

ellipse is first incised to the level of the fat. De-epithelialization of the overlying skin is done first using either a scalpel or dermatome. The underlying ellipse of dermis is then sharply excised. Some surgeons also take a thin layer of subdermal fat if bulk is required. The donor site is then closed in layers.

Case 1

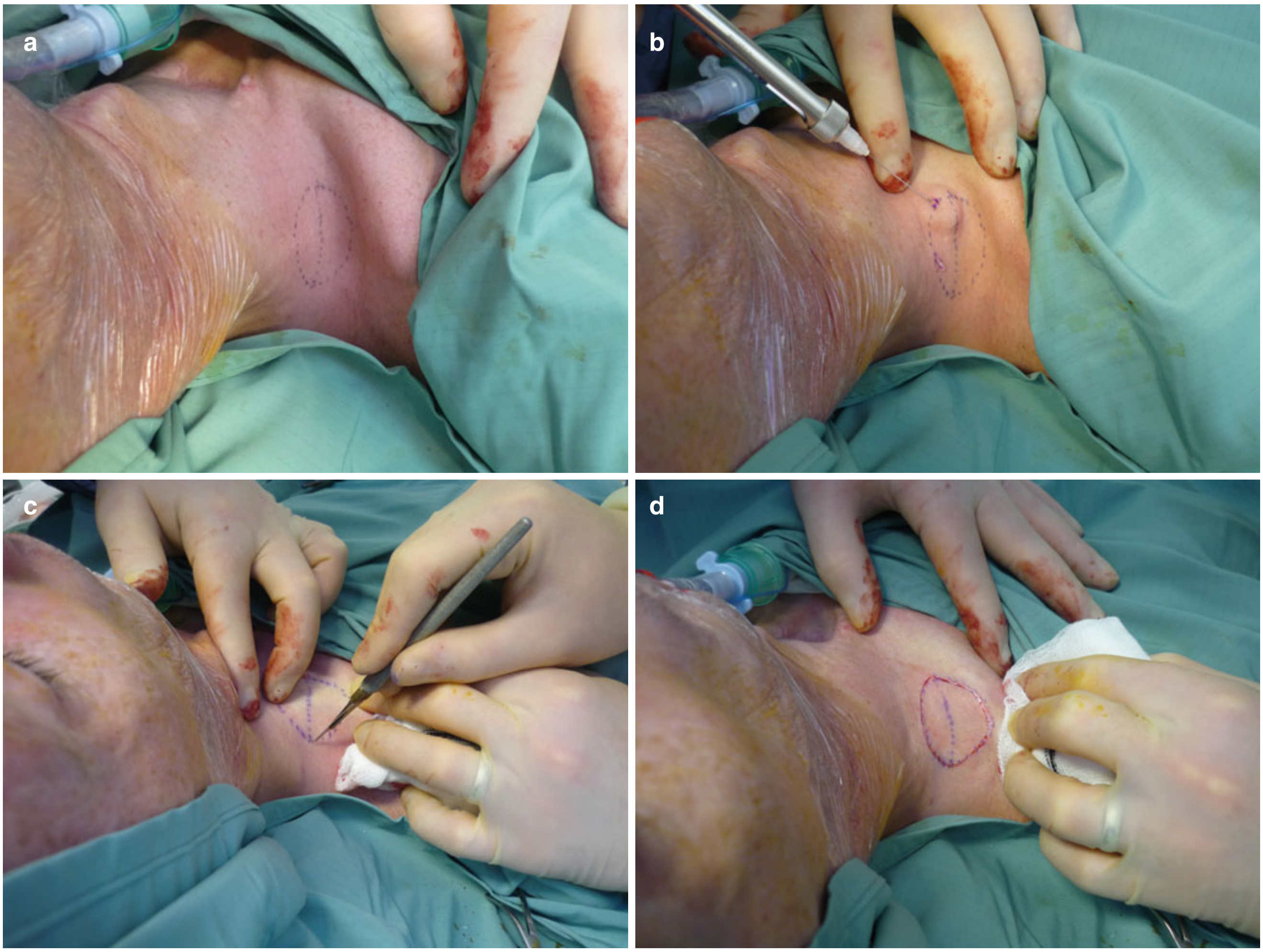

Fig. 18.52 (**a**–**f**) Harvesting of dermal graft. Initial skin incision and de-epithelialisation to expose underlying dermis. Note initial hydrodissection in the subdermal plane using local anaesthetic

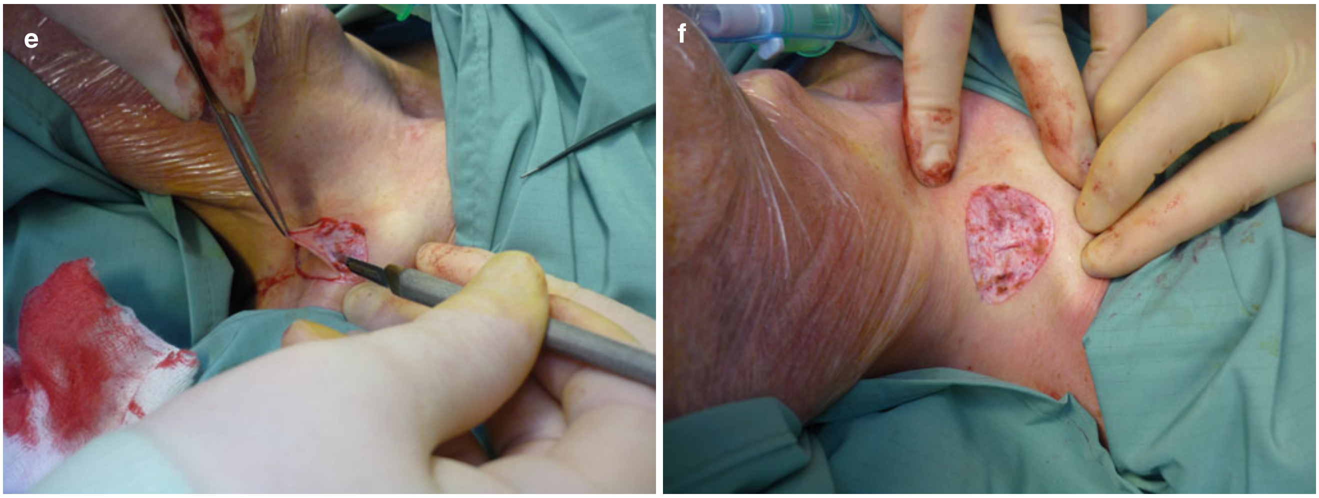

Fig. 18.52 (continued)

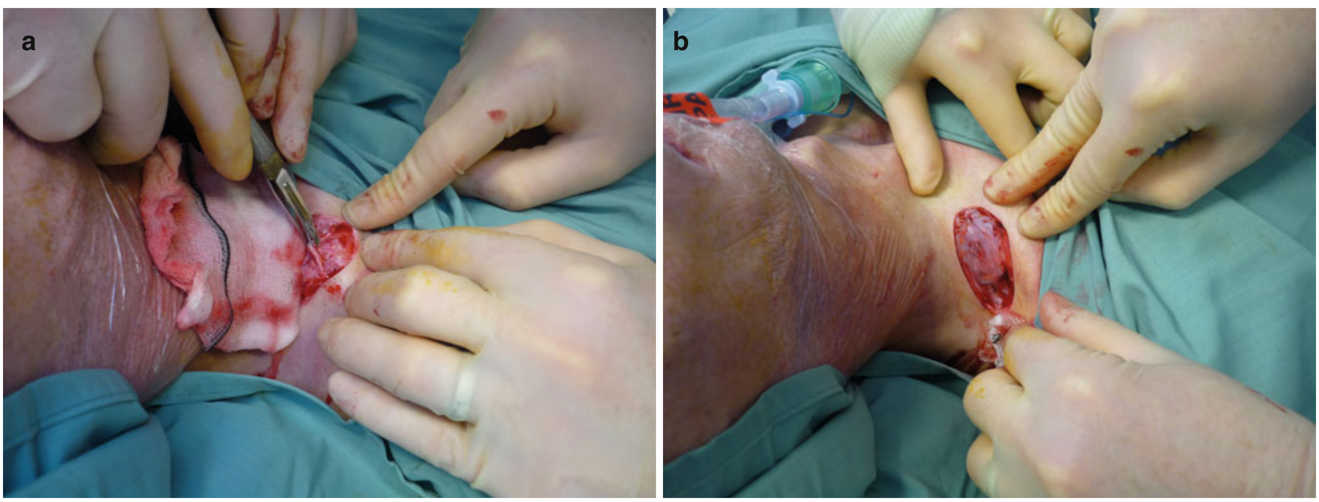

Fig. 18.53 (**a**, **b**) Dermal graft is raised as a second layer following de-epithelialisation

Fig. 18.54 Closure in layers

Case 2

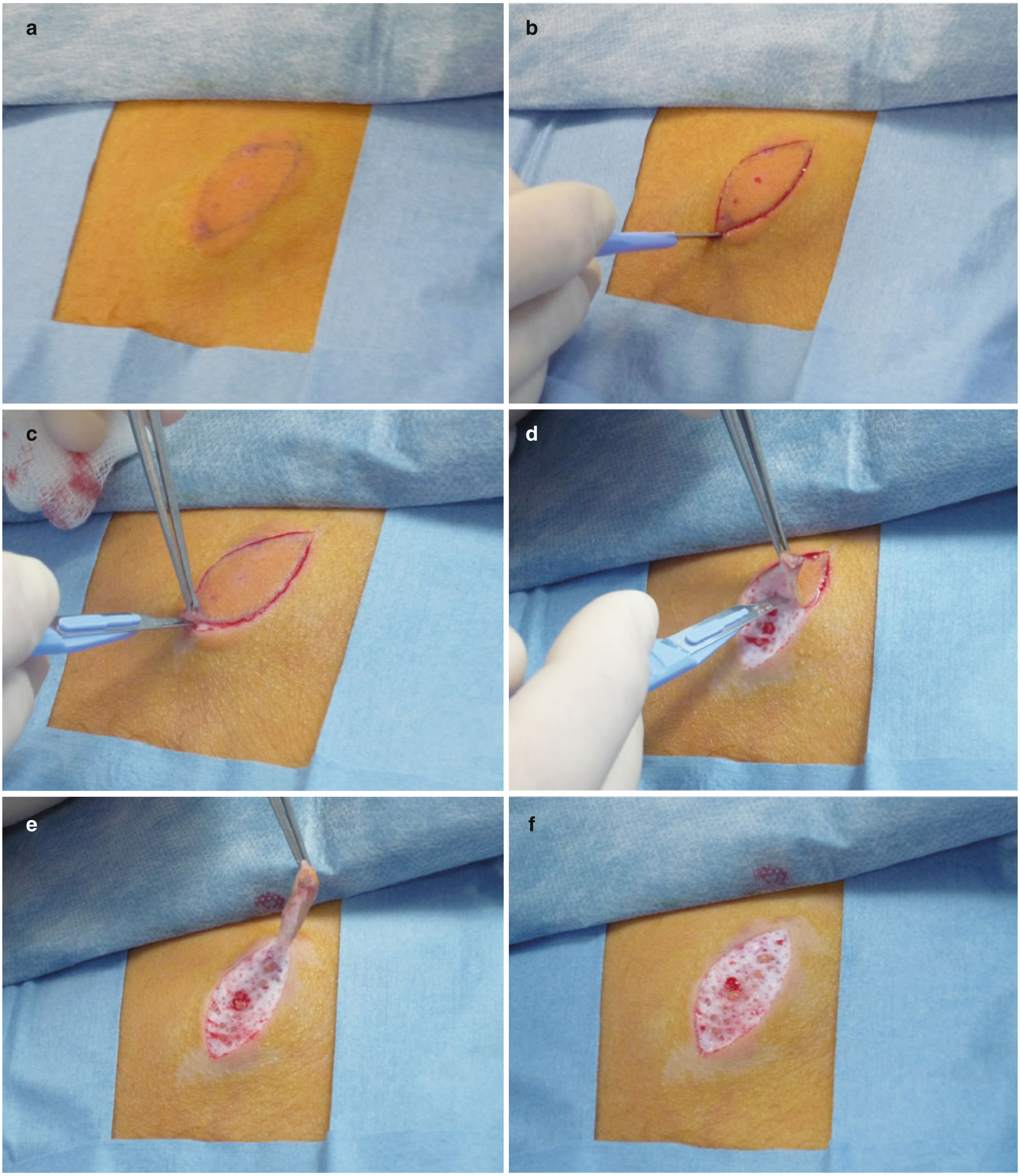

Fig. 18.55 (**a**–**e**) Harvesting of dermal-fat graft. Initial skin incision and de-epithelialisation to expose underlying dermis

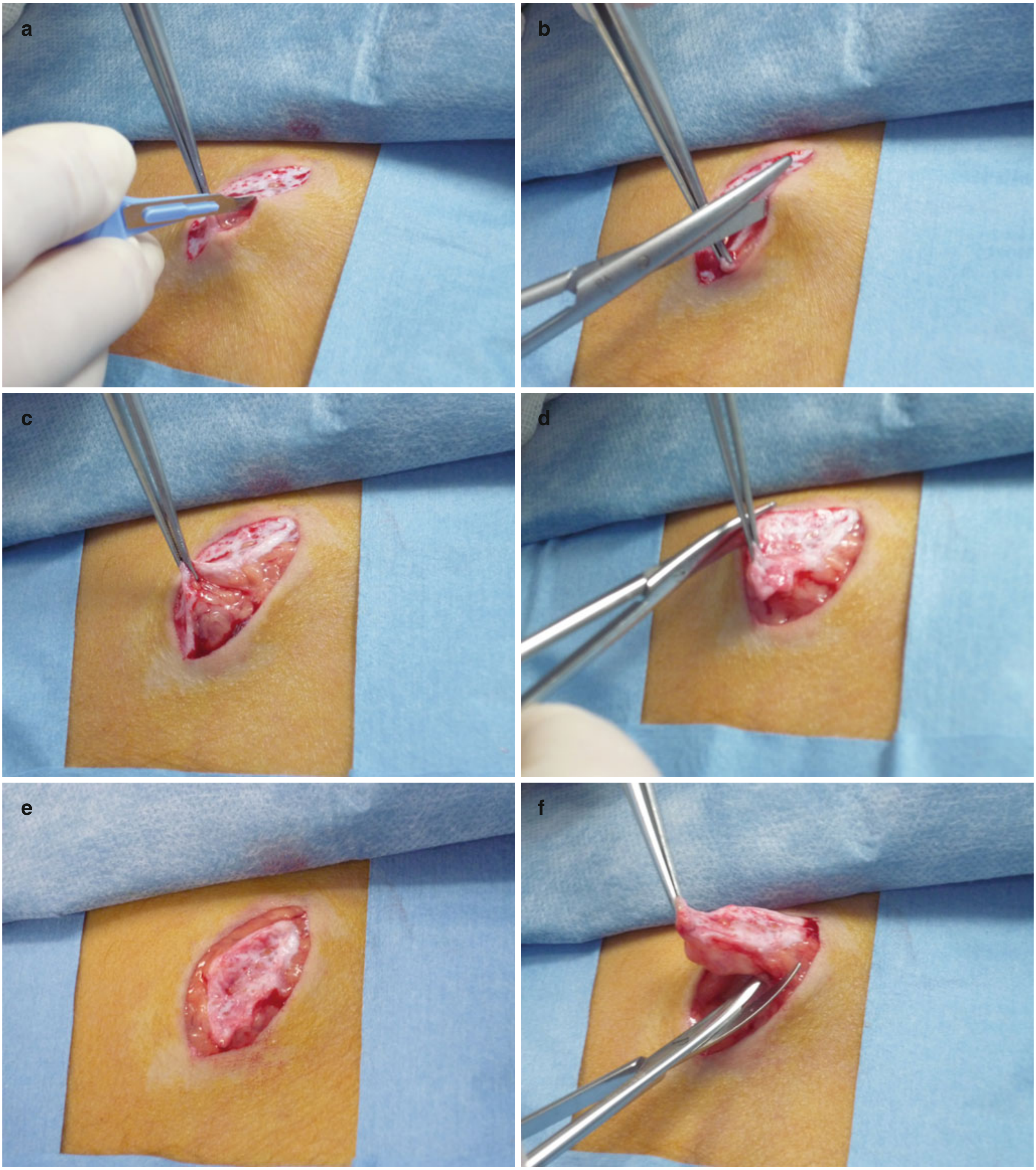

Fig. 18.56 (**a**–**f**) Dermis (plus fat) is raised as a second layer following full-thickness dermal incision and scissor dissection

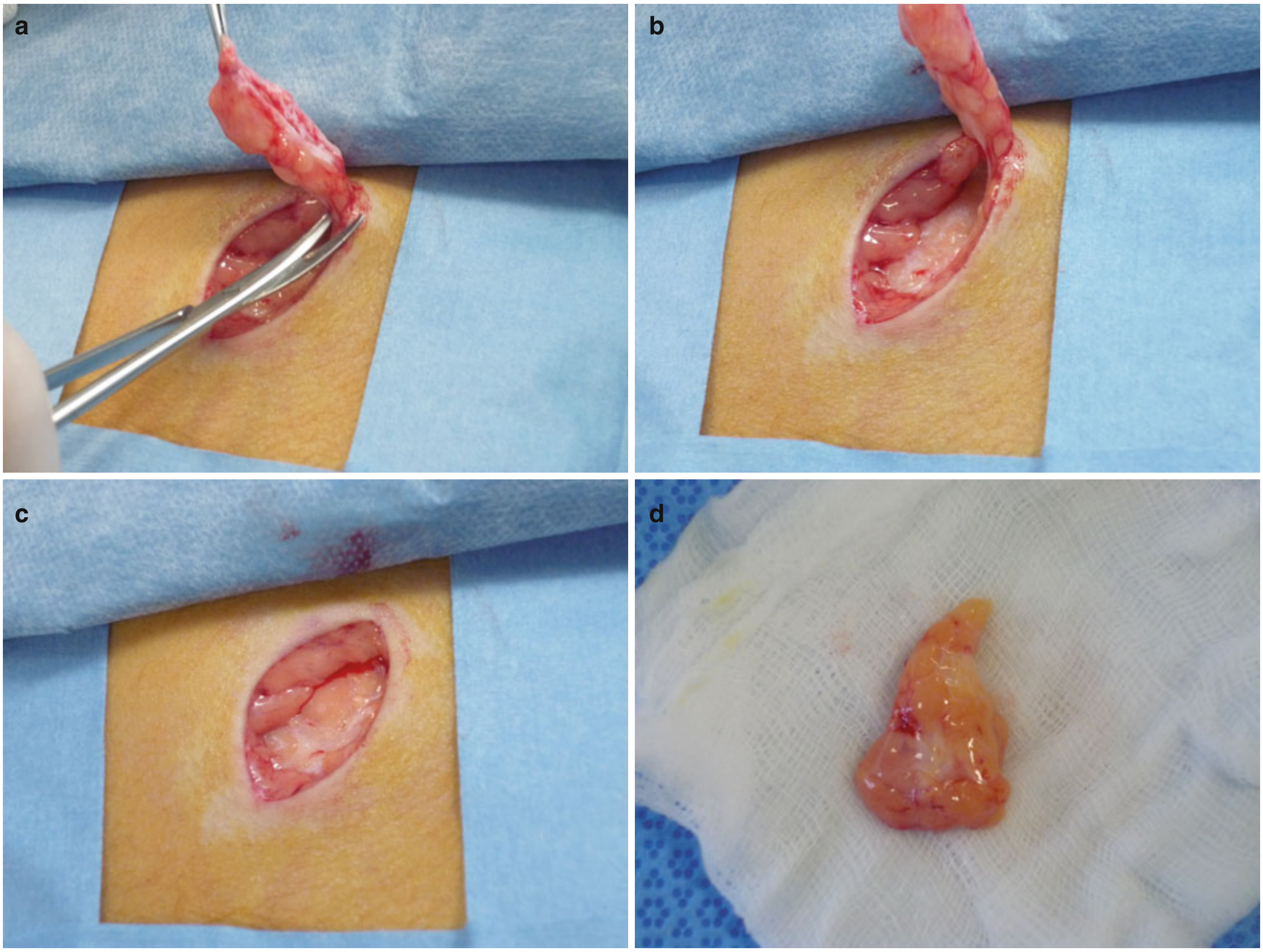

Fig. 18.57 (**a**–**d**) Completion of dissection and graft

18.5 Conchal Cartilage (Pinna)

Conchal (auricular) cartilage may be useful in the repair of the nasal tip, revision rhinoplasty or eyelid reconstruction. As long as the antihelical fold is maintained, no significant change in the appearance of the ear occurs, even if the entire concha is excised. In most patients, the cartilage is reasonably stiff but remains flexible. Depending upon where it is taken from, there is a degree of curvature to the cartilage which can be used to advantage.

Cartilage may be taken through a pre- or postauricular approach. In the preauricular approach, an incision is made just inside the antihelical fold. This is usually well-hidden postoperatively. In the postauricular approach, a large curvilinear incision or elliptical incision (if dermis is also required), is placed parallel to the long axis of the pinna.

Injecting local anaesthetic in the subperichondrial plane helps to "hydrodissect" the skin away from the underlying cartilage. Following incision, the skin and perichondrium are raised from the underlying cartilage using scissors or a periosteal elevator. Care is taken not to damage the soft auricular cartilage, which can easily splinter and tear. Anteriorly, dissection proceeds to the external auditory canal. In the postauricular approach, the thicker skin and perichondrium is elevated to expose the cartilage.

When adequately exposed, the cartilage is then incised to define the periphery of the graft. As it is cut it tends to gape to expose the underlying soft tissues. The skin and soft tissues on the opposite side are then elevated in the subperichondrial plane and the graft is removed. Haemostasis is important to prevent a "cauliflower ear" deformity. The wound is then closed and a pressure dressing applied for 7–10 days.

Case 1

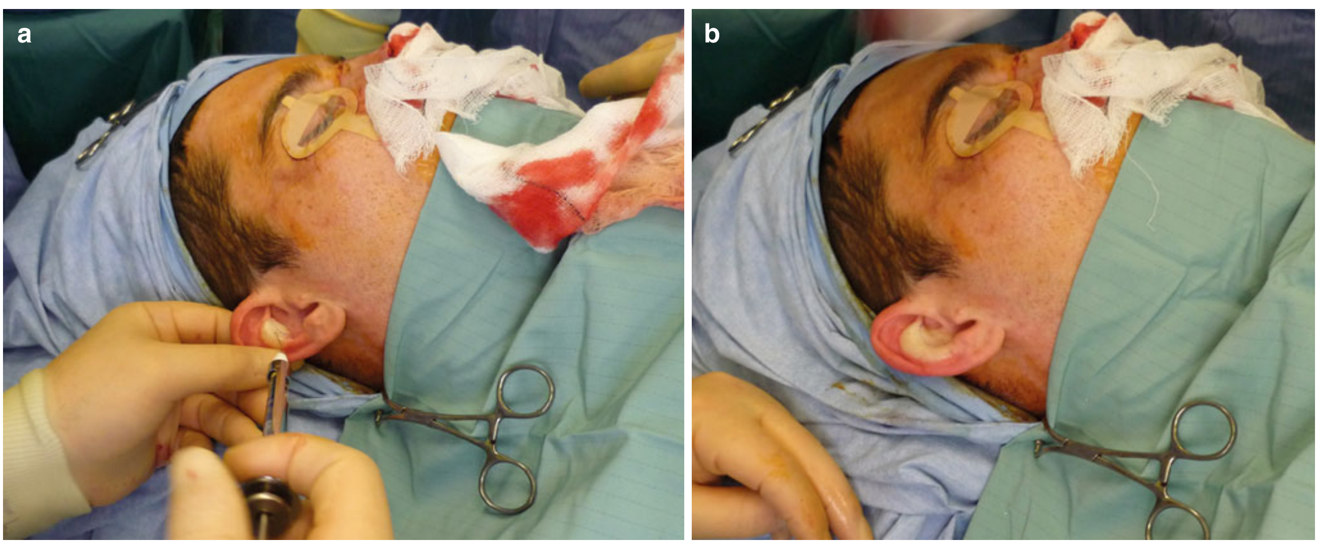

Fig. 18.58 (**a**, **b**) Harvesting of conchal cartilage (anterior approach). Initial hydrodissection using local anaesthetic

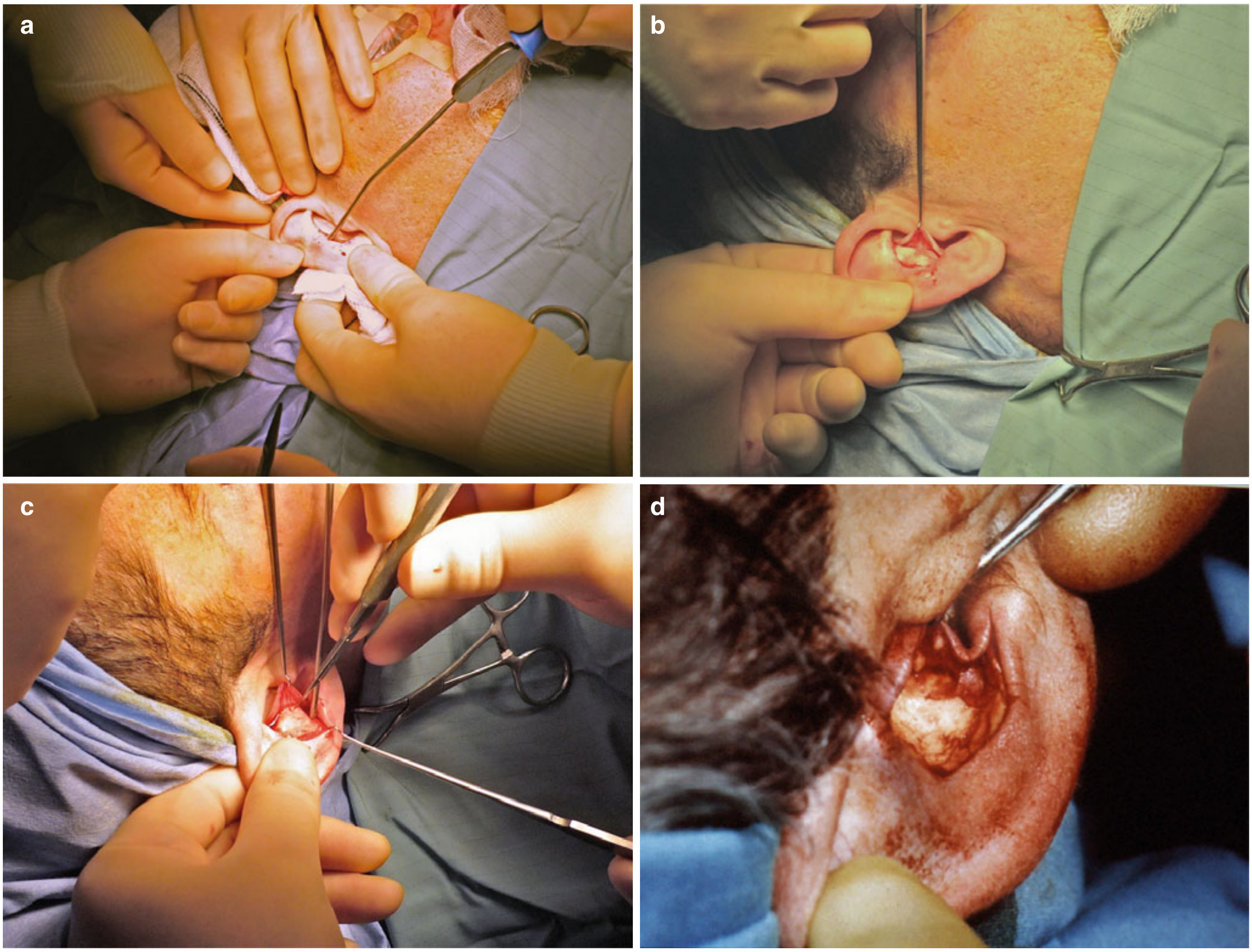

Fig. 18.59 (**a**–**d**) Following initial skin incision along conchal bowl, the skin is elevated off the cartilage

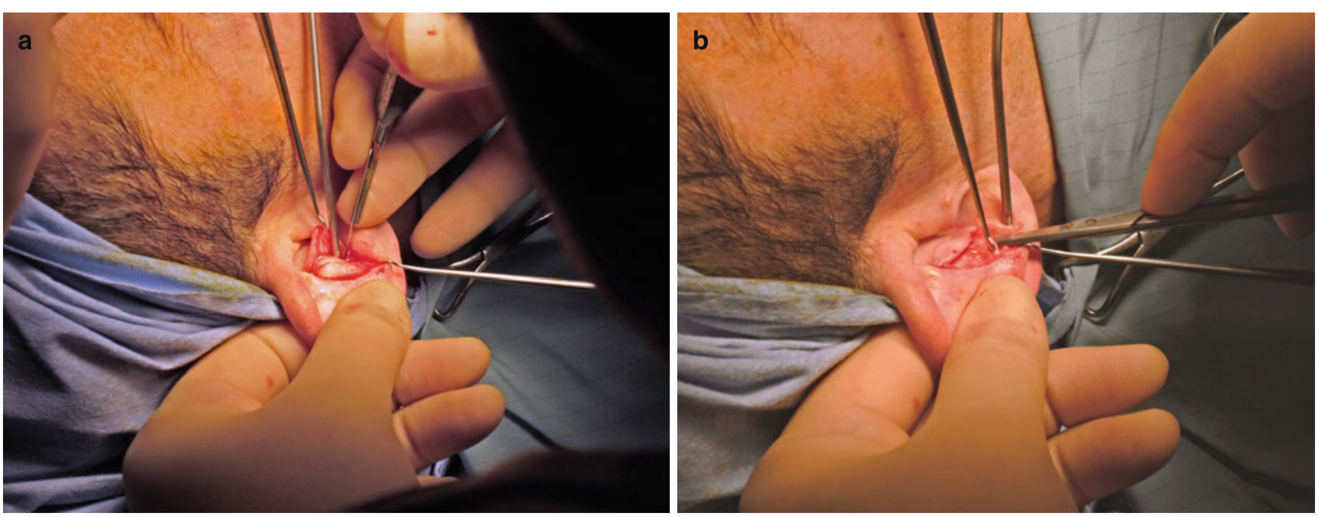

Fig. 18.60 (**a**, **b**) The exposed cartilage is incised and dissected from the deeper soft tissues. Care is required as the cartilage can easily splinter

Case 2

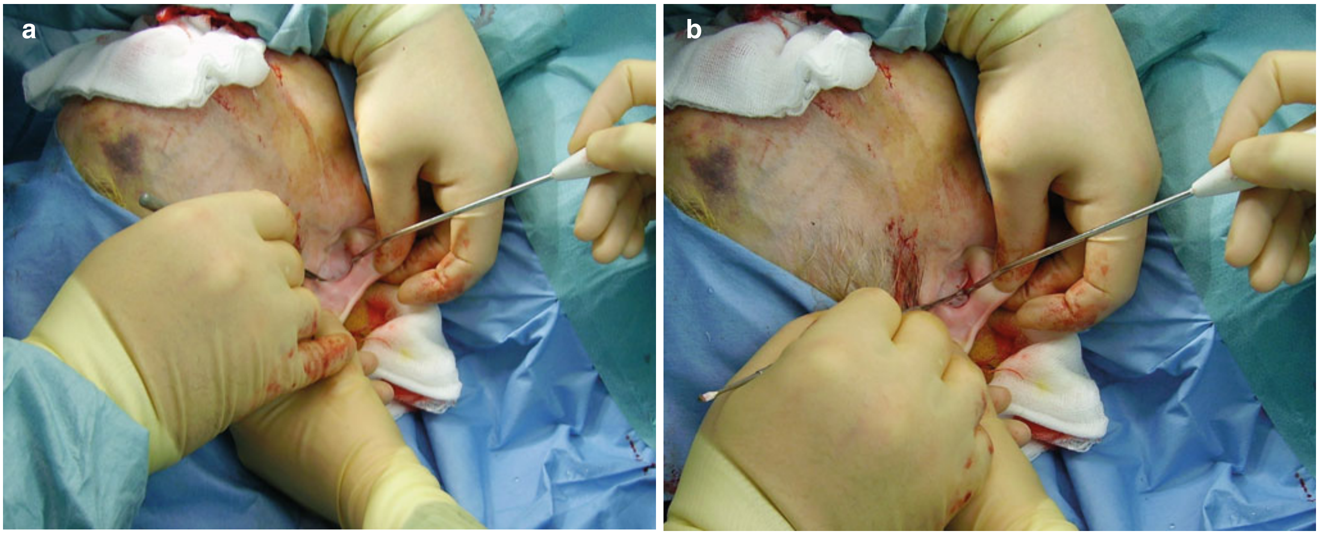

Fig. 18.61 (**a**, **b**) Following initial skin incision along conchal bowl the skin is elevated off the cartilage

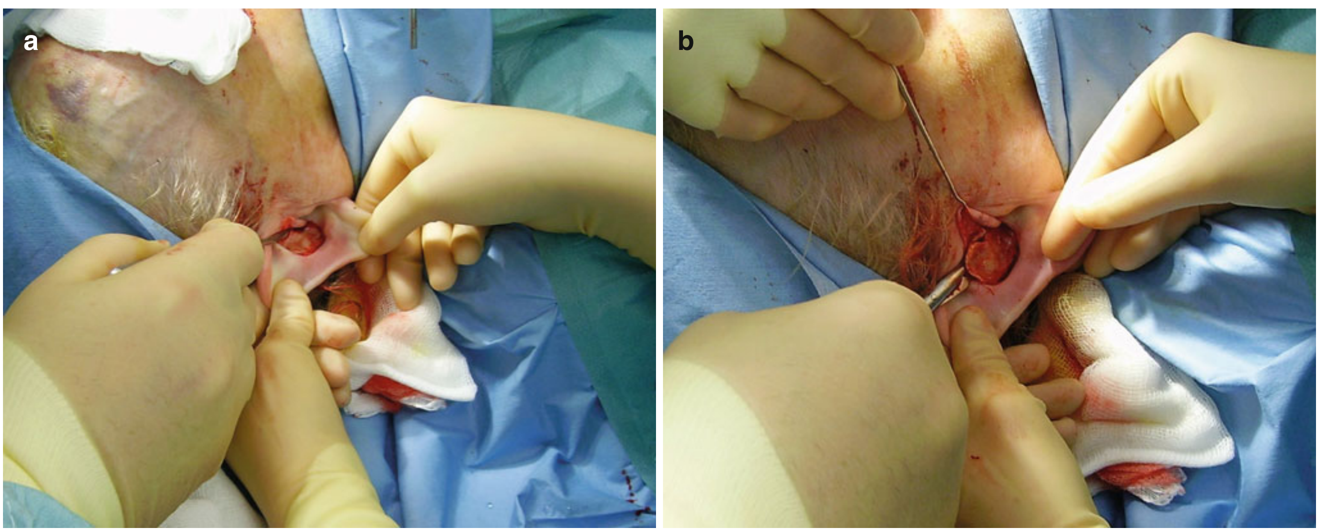

Fig. 18.62 (**a**, **b**) The exposed cartilage is incised and dissected from the deeper soft tissues

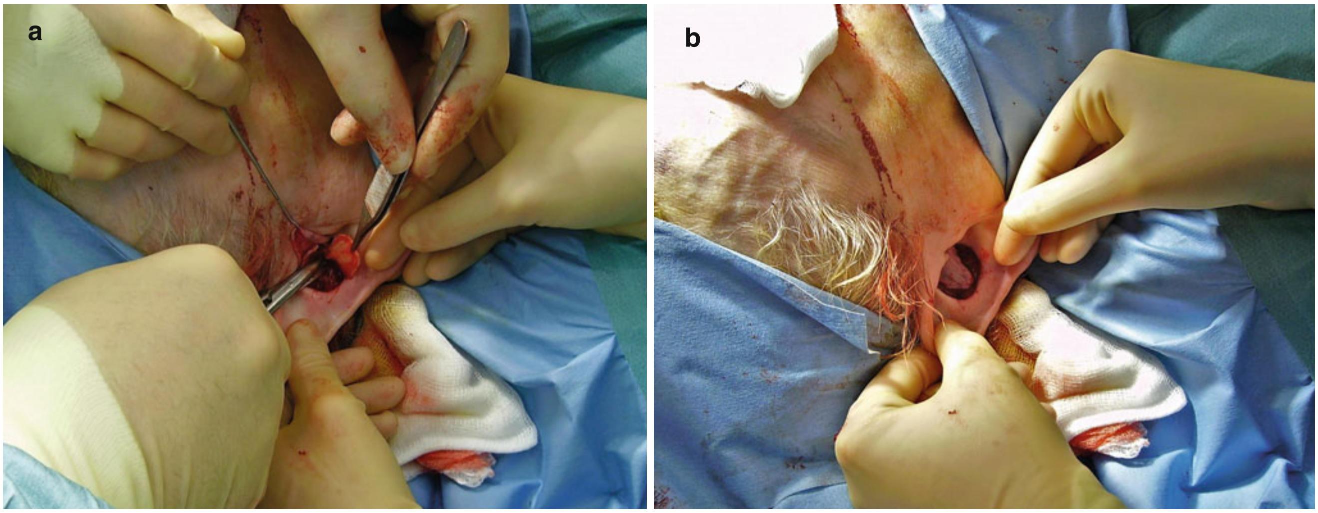

Fig. 18.63 (**a**, **b**) Completion of deeper dissection and removal of graft. Surgical bed with overlying anterior skin flap

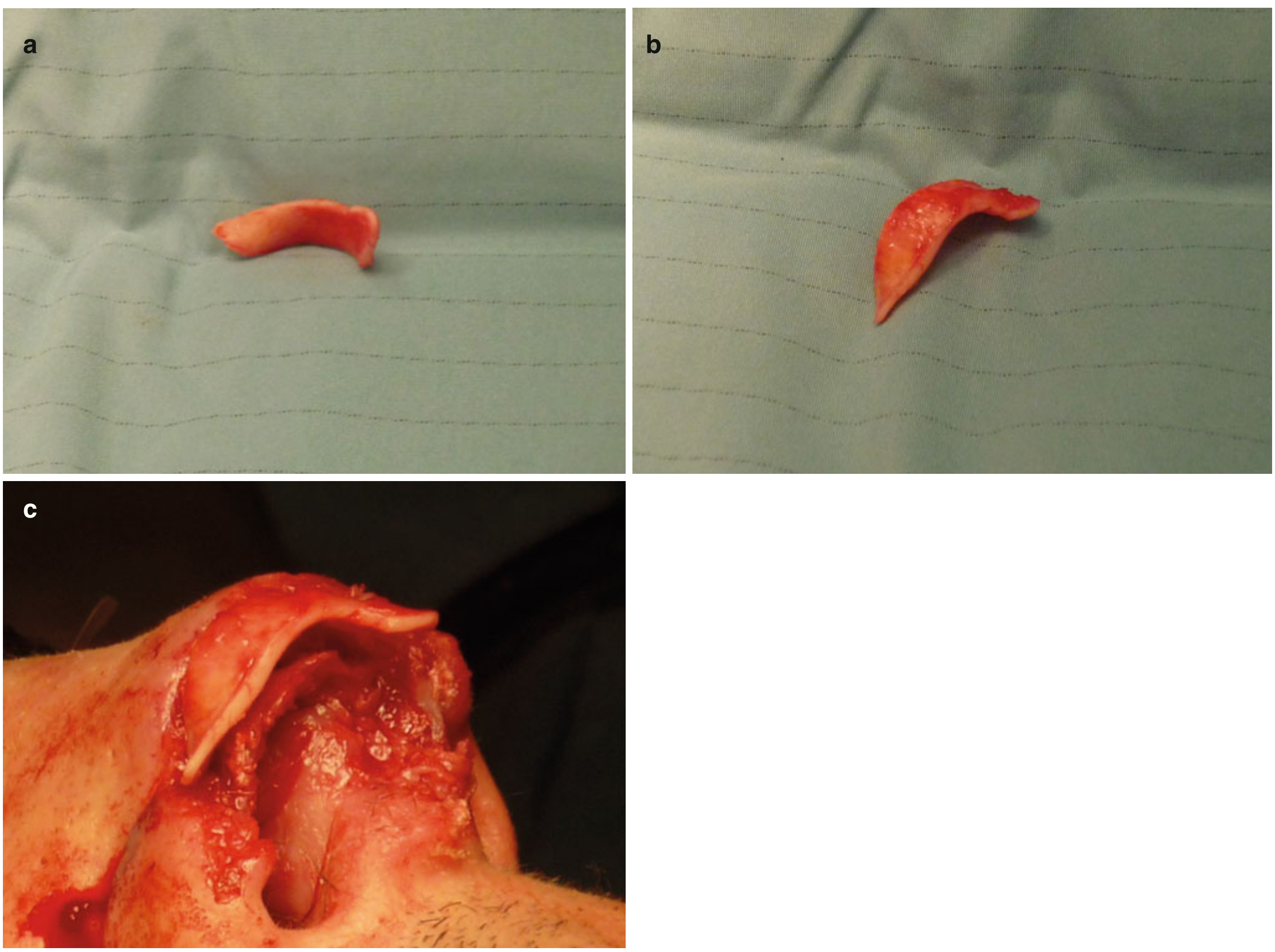

Fig. 18.64 (**a**–**c**) Graft and initial sizing

Case 3

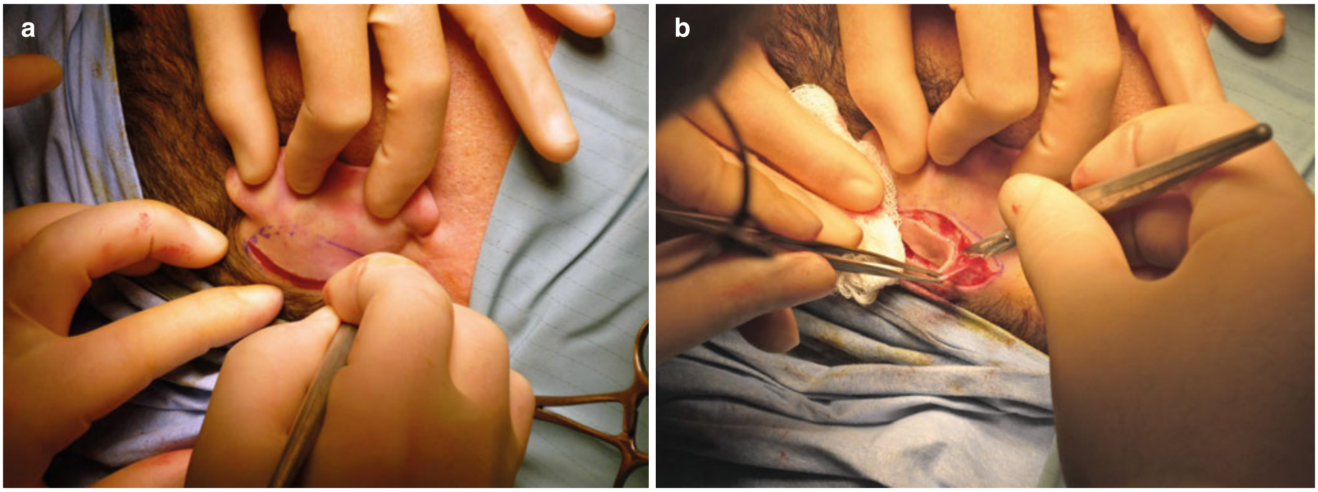

Fig. 18.65 (**a**, **b**) Harvesting of conchal cartilage (posterior approach). An ellipse of skin is excised to expose the cartilage

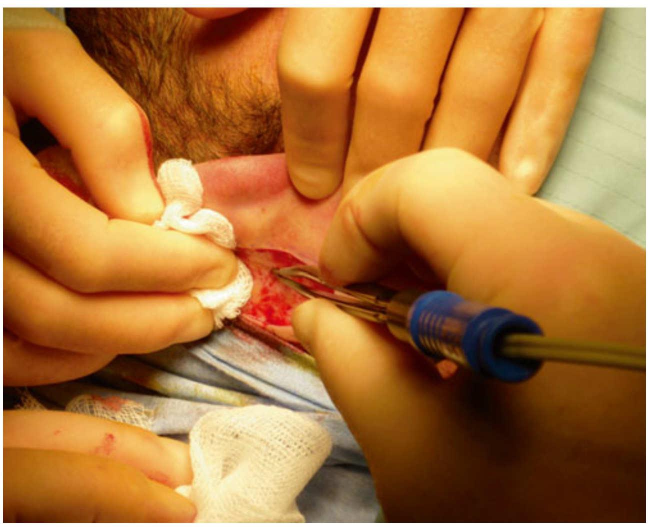

Fig. 18.66 Cartilage is excised using similar technique as previously described

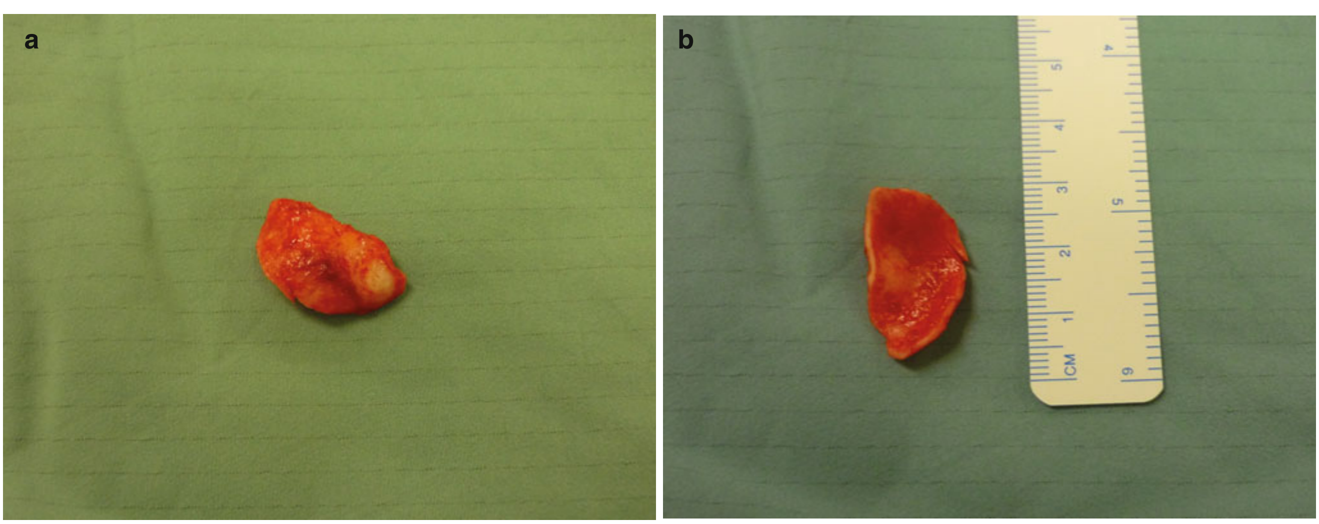

Fig. 18.67 (**a**, **b**) Harvested graft

Case 4

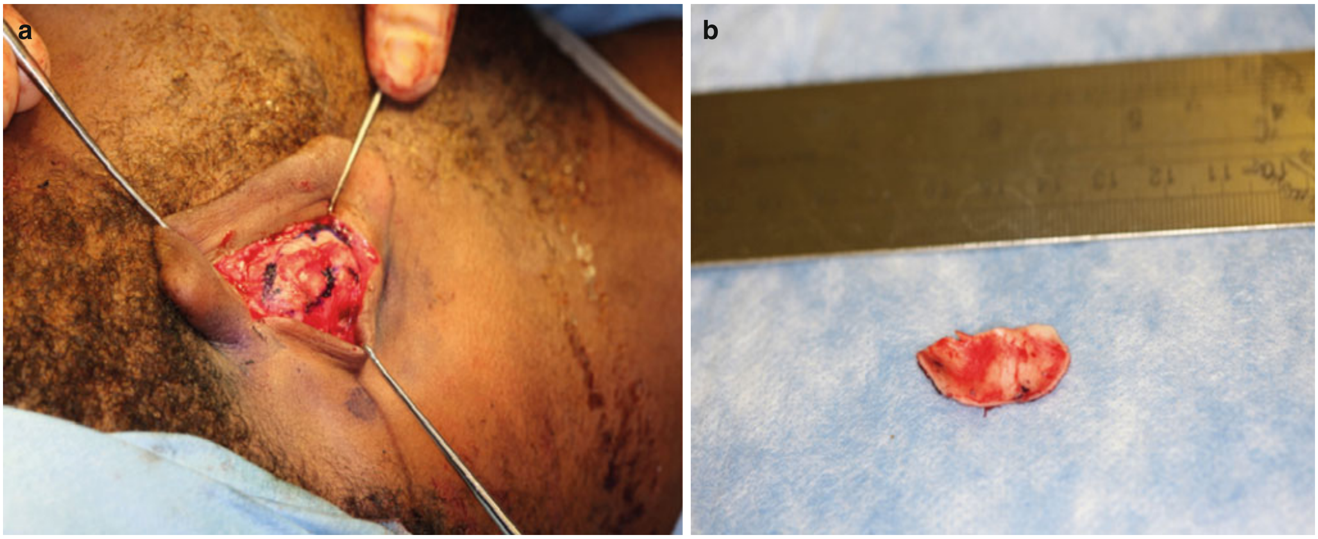

Fig. 18.68 (**a**, **b**) Harvesting of conchal cartilage (posterior approach). An ellipse of skin is excised to initially expose the cartilage

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Aftercare and Follow-up

19

Michael Perry

In contrast to the assessment, management, and complications of facial injuries, comparatively little has been published specifically addressing the follow-up process in trauma and the particulars of aftercare. Postoperative care protocols vary considerably and are often based on individual experiences, rather than any rigorous evidence base. Patients may be followed up for only a month or two, or they may be kept under review for a number of years depending on the surgeon's interest, ongoing complications and need for further surgery. Financial and other constraints may also influence the decision to discharge patients. Yet one can argue that long-term follow-up is essential to enable us to assess (and publish) long-term outcomes, necessary for "quality control." How can we say we are "good" at anything, if we don't see and critically analyse the long-term results? Lack of complications does not necessarily mean a good outcome. Nevertheless, a pragmatic approach is often required, particularly in centres where high volumes of trauma and limited resources make it impossible to provide long-term follow-up for every patient (Table 19.1).

Table 19.1 Some useful "facts" to help follow-up

Most fractures are healed sufficiently to support functional loads (notably biting/chewing) by about 1 month. Comminuted fractures may take a little longer.
Enophthalmos is usually noticeable by about 3 months, if not sooner.
Minor residual diplopia can take many months to resolve (or not).
Metal work can become infected within days or it may take years (smokers are especially at risk).
Soft tissue injuries and scars can take 18 months or longer to mature enough to give an indication of long-term results.
Lymphoedema can take many months to settle. It is much more noticeable around the eyelids.
Nerve injuries can take 18 months or longer to recover.
Mucocele formation (notably frontal sinus and lacrimal) can take several (or more) years to become clinically apparent.
Some authorities believe the risk of meningitis following inadequate management of the frontal sinus is life-long.
Condylar resorption can take years to become clinically apparent.
Dental/periodontal complications can take several years to become clinically apparent.
Psychological complications can last a lifetime.

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19.1 Postoperative Advice and Instructions

During the initial postoperative period, a number of points need to be addressed. Many are based on personal experience and opinion.

19.1.1 Oral, Nasal, and Wound Hygiene

The importance of good oral hygiene needs to be emphasised to patients, especially when intraoral lacerations or incisions have occurred, or intermaxillary fixation (IMF) is in place. Many regimes exist, from hourly hot salt water mouth washes, to a number of antiseptic mouthwashes (usually rinsed approximately four times a day). Gentle tooth brushing should also be encouraged whenever possible. The ideal frequency of mouthwashes is not known, but after meals and before going to bed seem to be logical times, in order to remove any left-over debris which can collect. If salt water is used (and not swallowed) this can be encouraged as frequently as possible. It is important to be aware that some mouthwashes (such as chlorhexidine) can stain enamel if used excessively.

Nasal hygiene is also important following fractures to the nose, nasoethmoid region, or when sinus drainage may be impeded. Although gentle nose blowing (with care) may be allowed in some cases, vigorous blowing should be avoided initially. Regular saline douches help clear away dried blood and

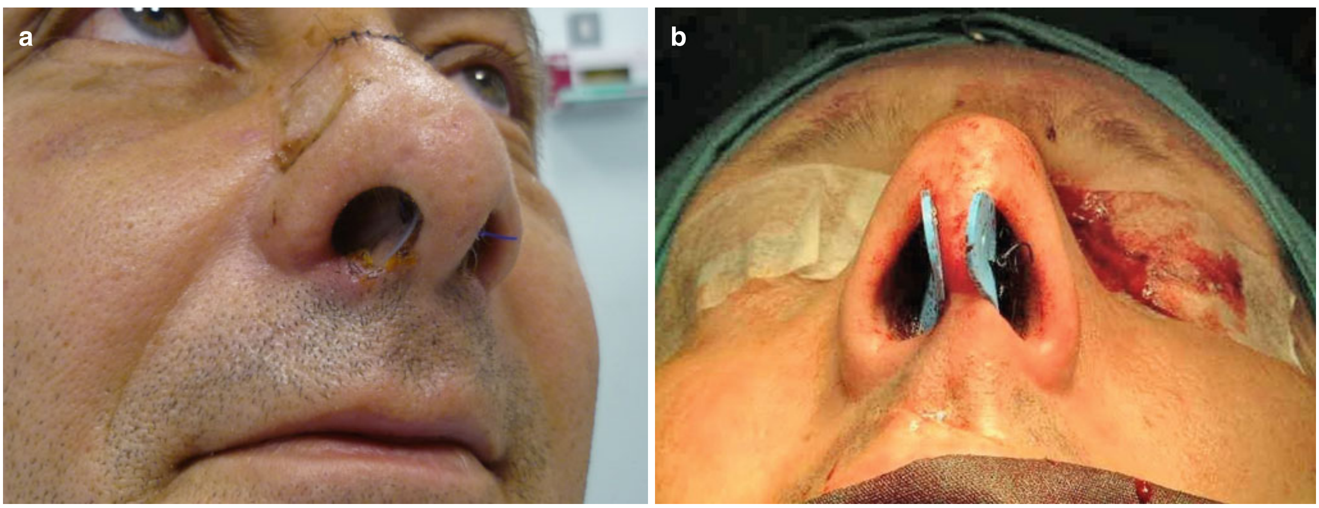

Fig. 19.1 Nasal hygiene is important to remove mucous and old blood, both of which may harbour potentially pathogenic organisms and impair drainage from the sinuses (**a**). The presence of nasal splints requires particular care due to risks of infection (**b**)

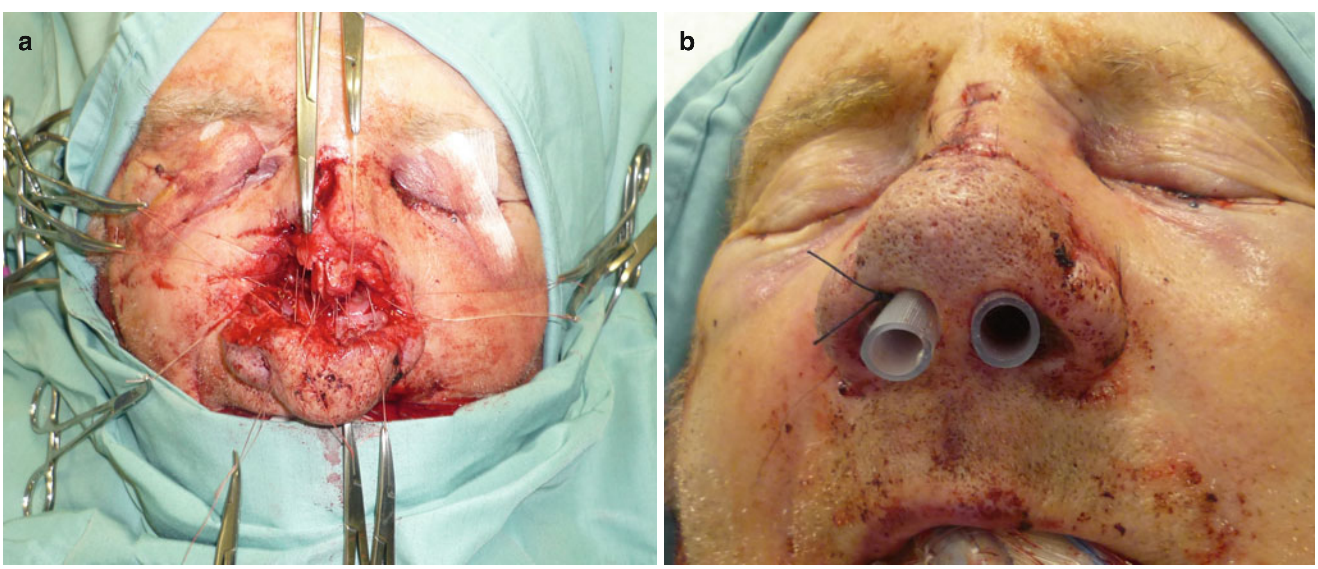

Fig. 19.2 Through-and-through lacerations of the nose (**a**), requiring a layered closure, are at risk of stenosis. Stents may help reduce this (**b**), but may be required for some time. Nasal hygiene is important, but no guarantee against infection

Fig. 19.3 Clean wounds like this may be left undisturbed until the sutures have been removed. They can then be gently cleaned and the Steri-Strips reapplied regularly to maintain continued support

mucus, improve sinus drainage and hopefully reduce the likelihood of infection. Various solutions exist, but a simple homemade remedy contains one teaspoon of table salt plus one teaspoon of baking soda (to adjust the pH) in a cup of lukewarm tap water. This is gently poured or sprayed into the nasal cavity. Steam inhalations supplemented with decongestants (such as menthol) are also helpful. Topical vasoconstrictors should only be used for a limited period of time (approximately 10 days).

Skin wounds can be allowed to get wet the day after repair if so required. The scalp and face can be washed if the patient wishes, but clearly they must avoid scrubbing or vigorous drying. Alternatively if the wound is dressed the site can be left for a week until the stitches have been removed. Steri-Strips need to be regularly applied once they start to peel off. The skin should be gently cleaned before each application. If external fixation has been used, the pin sites need to be carefully cleaned and monitored for signs of infection.

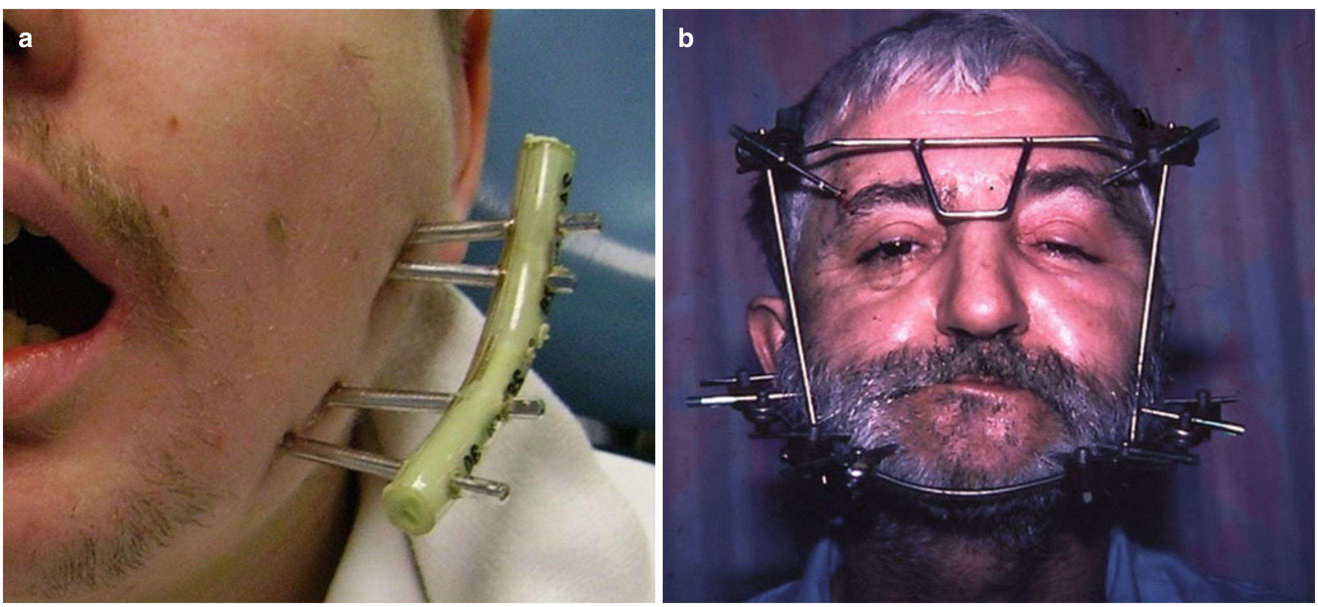

Fig. 19.4 (**a**, **b**) If external fixation has been used, the pin sites need to be kept clean by the patient. Since external fixation is generally reserved for high-energy–type injuries, or infected fractures, these patients are at risk of infection

19.1.2 No Nose Blowing

This is usually advised in patients who have sustained fractures through any of the sinuses or anterior cranial fossa (i.e., most fractures occurring above the occlusion). The concern here is that any forceful Valsava manoeuvre will force air (and bacteria-containing mucus) through the fractures and into the soft tissues, or intracranially. This carries the risk of severe infection, tension pneumocephalus or retrobulbar emphysema with proptosis. In theory, flying also carries a small risk of these happening, but there is little in the literature on the subject. Some surgeons permit unilateral, gentle blowing of the nose, without any closing of the nostril (sometimes eloquently referred to as a "farmer's handkerchief"). If the patient has to sneeze, they should do so with the mouth open. Although these are all designed to avoid a rapid build-up of pressure within the nasal cavity, the clinical benefits, although theoretical, are not extensively reported on. How long someone should refrain from nose blowing is also subject to debate. Three to six weeks seems to be common practice.

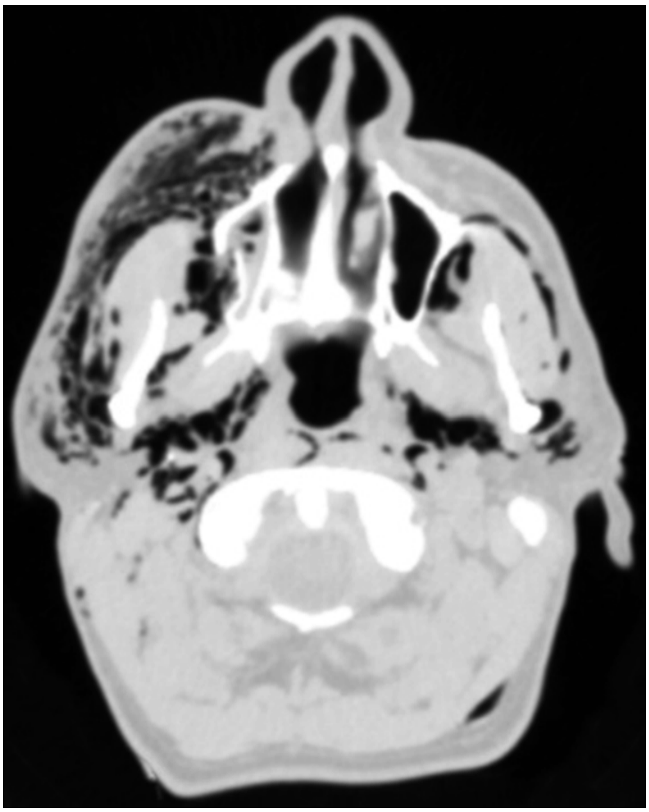

Fig. 19.5 Massive surgical emphysema (extending into the mediastinum) in a patient who repeatedly blew their nose following midface injuries

19.1.3 Postoperative Imaging

In recent years there has been a growing argument against the taking of "postop views" following repair of routine fractures. This is an interesting topic and one that is somewhat controversial (Table 19.2).

While a small number of good publications have challenged the need for postoperative views, at the moment, withholding imaging is not widespread practice. Conversely, with the increased speed and precision of computed tomography (CT) scanning (plus the lower radiation doses with newer machines), some surgeons now opt for this as the modality of choice in assessing repair of complex injuries, especially those involving the skull base, orbits and nasoethmoid region. Only with CT can the "deeper" aspects of the repair by visualised (notably in orbital fractures).

19.1.4 Antibiotics

Postoperative infection and the role of antibiotics are two areas which have been extensively published about. Yet many antibiotic preferences and regimes still exist. If it is felt that antibiotics are required they should ideally be commenced at the time of surgery (or on admission), rather than

Table 19.2 The case for and against postoperative imaging

Imaging is necessary because:	Imaging is not necessary because:
This verifies satisfactory reduction (or not). Without postoperative views, we cannot evaluate our results, improve care, or train future specialists. Medicolegal reasons: if the patient returns with fracture displacement, is this a surgical failure, or did they just get another injury?	The surgeon should know if his repair has been adequate or not (especially if this was an open reduction). It reduces radiation to the patient. In the vast majority of cases it does not alter what we do—the decision to reoperate is usually based on clinical assessment. Patients should not have x-rays taken solely for medicolegal reasons or training purposes.

postoperatively. Bacterial resistance is an ever-present concern which needs to be balanced against the risks of developing infection. However, some risk factors may not be as influential as traditionally taught (e.g., delays in mandibular repair). Ideally all established infections should be reviewed every 48 h when the need for antibiotics is then reassessed. Unfortunately, this may not be practical or possible in every case. Discussion with your local microbiologist may be of value and local audits help define best practice locally.

19.1.5 Postoperative Elastic IMF

The correct use of IMF is important, especially when condylar fractures are present. If wires have been used, close observation in the immediate postoperative period is required. Because of the risks to the airway, patients may remain in hospital longer. Prior to discharge, the patient must be provided with wire cutters which must be with them 24 h a day. For these (and other) reasons, wire IMF is now rarely applied.

With elastic IMF, the decision to apply elastics (or not) following semirigid fixation in mandibular fractures, and how "tight" the IMF should be, depends on a number of assumptions and factors. With simple fractures and single-site fractures, IMF may not be required at all if an anatomical repair has been performed and the patient can occlude normally with minimal effort.

Fig. 19.6 Wire IMF poses an immediate risk to the airway. Patients should have wire cutters with them 24 h a day, although this is no safeguard against aspiration

The rationale for elastic IMF is to provide additional support to mandibular fractures, while at the same time enabling some "fine tuning" of the occlusion if the fracture has not been anatomically repaired. Anecdotally, elastic IMF appears to allow a small degree of adjustment, presumably by encouraging the dentition or fracture to align, although very little has been published regarding this mechanism. However, this is an unpredictable phenomenon and should not be relied upon as a bail out for a poor repair. With fractures of the condyle, elastic IMF (rather than wire IMF) is thought to enable the

fracture to partially realign under functional activity, to such an extent that the occlusion can be re-established and the joint can function adequately. With the teeth intermittently in occlusion, the condyle is free to reposition itself during function. This is a somewhat controversial topic.

How long elastics should be used for, is also poorly discussed in the literature and is often based on personal experience. Since most fractures are quite firm after 4 weeks, any benefit following this will presumably be minimal.

19.1.6 Return to Normal Diet

In view of the time required for mandibular and midface fractures to firmly unite, 4–6 weeks of "soft diet" seems to be an appropriate length of time for most fractures. Considering the significant amount of bite force a healthy mandible can generate, this is an interestingly short period when one compares to the extremities (which may require 3–4 months immobilisation before weight bearing).

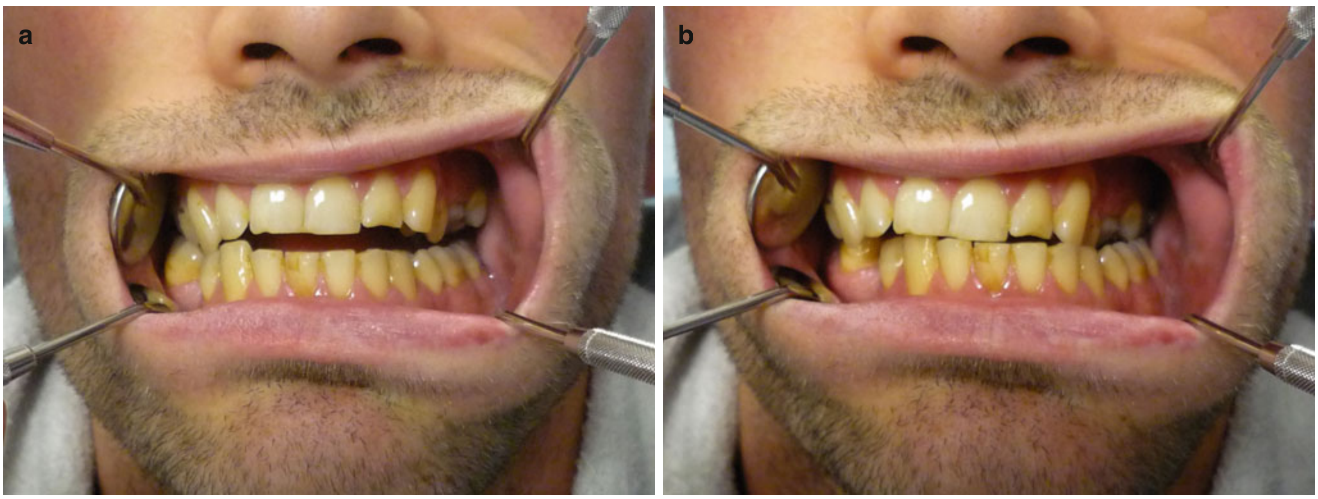

Fig. 19.7 Correct assessment of the occlusion is more than just asking the patient to "bite together." This can be misleading. In this case (**a**, **b**), an apparent dysocclusion was in fact normal for the patient, verified by group function of the teeth, patient's evaluation of their bite and the anatomical reduction seen on the radiographs. IMF was not required

Fig. 19.8 Depending on the number of hooks used and elastics applied, IMF can be "light" or "heavy"

19.1.7 Routine Plate Removal

This is a controversial issue. A number of papers have been published describing the migration of titanium particles into the neck and further afield, thereby questioning how inert titanium really is. The very long-term effects of titanium are still unknown. Some centres routinely remove plates and screws, although currently there is little evidence that clearly demonstrates this is necessary. Other centres do not remove plates unless there have been significant complications.

Fig. 19.9 Facial exercises are an important part of the rehabilitation process. Like all musculoskeletal injuries, the soft tissues need to be encouraged to return to normal function—"facial physiotherapy"

19.1.8 "Facial Physiotherapy" and Rehabilitation

A number of neuromuscular exercises may be useful following repair of facial injuries. Essentially these are all just a form of postoperative physiotherapy in keeping with the philosophy of "facial orthopaedics." The precise exercise required depends on the injuries sustained.

Following orbital surgery, eye patches should be avoided and extraocular muscle activity ("eye exercises") encouraged. A minor degree of diplopia is usually common and occurs as a result of swelling and minor injury to the muscles. This should quickly recover. Patients should be encouraged to look in the direction that gives them diplopia as this helps in recovery and the central fusion process. If diplopia is significant or persists, an ophthalmic/orthoptic opinion should be sought, since corrective prisms may be required. Failure of diplopia to resolve or be corrected with prisms can result in permanent inability to undergo fusion later.

With mandibular fractures, once the fracture has sufficiently united, patients should be encouraged to mobilise the jaw. Prolonged IMF can result in restriction of mouth opening, secondary to capsular contraction at the temporomandibular joints. By way of analogy, stroke patients require regular full range of joint movements in order to prevent joint contractures. Prolonged immobilisation in any joint can

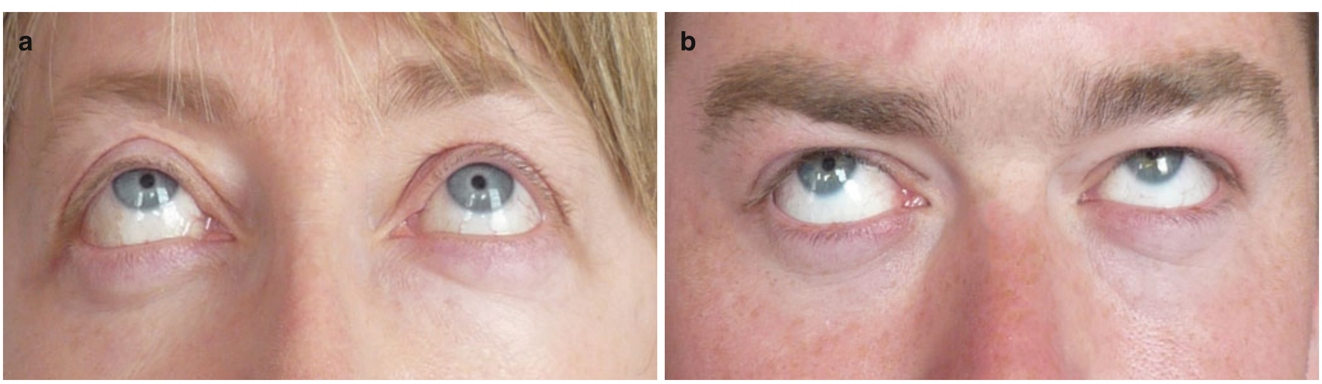

Fig. 19.10 Minor degrees of diplopia at the extremes of gaze are common following orbital repair. This usually resolves following ocular motility exercises, but ideally should be monitored (**a**, **b**)

result in contractures. In addition, prolonged immobilisation (such as from a stroke, plaster cast or IMF) can result in weakening and atrophy of the muscles. These need exercising afterwards. Many protocols and devices are currently available to manage these complications. Chewing gum and stacked lollipop sticks are a cheap alternative. The most important factors are patient motivation and compliance. "Little and often" is the best way to stretch tissue and build up muscles. Patients need to be encouraged to follow regular regimes.

The surrounding soft tissues should also not be forgotten. Lymphoedema needs regular massage to encourage the adjacent lymphatic ducts to drain the fluid. This is particularly obvious around periorbital wounds. Scars need appropriate support and massage. Silicone sheets and gels are commonly used to minimise excessive scar tissue formation. In some reports, botox has been shown to prevent scars stretching, by weakening the underlying muscles.

High-energy injuries can result in fibrosis, not only in scars but also in the intact deeper tissues and muscles. These

Fig. 19.11 Successful rehabilitation of the mandible is more than just restoring the occlusion. Patients should be encouraged to open the mouth and move the jaw forwards and sideways (**a**, **b**). Limitation in mouth opening is common after treatment of mandibular fractures but can usually be overcome with appropriate exercises

often need vigorous massage and other exercises to facilitate neuromuscular recovery. Some authorities recommend gently rubbing areas of persistent numbness. This is thought to enhance sensory recovery by a combination of nerve recovery and ingrowth of adjacent sensory nerves (a process sometimes referred to as collateral spouting). In all these treatments, the most important element, however, is patient compliance to a long-term regime.

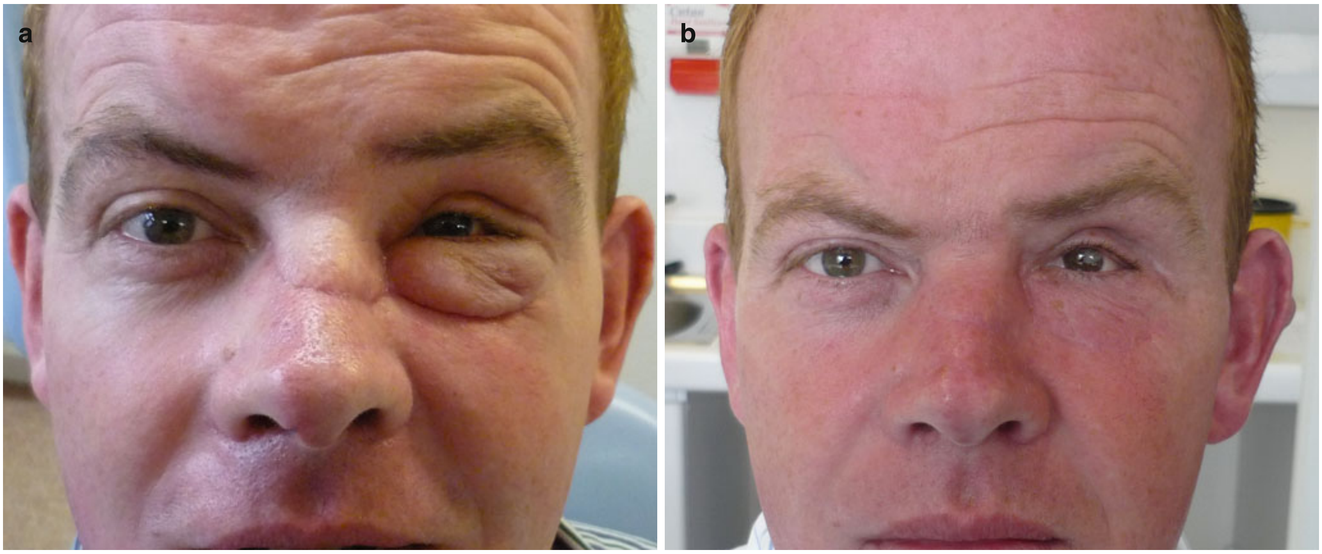

Fig. 19.12 The benefits of massage in a highly compliant patient are seen here (**a**, **b**). Almost total resolution of the swelling had occurred in just 2 months. The left globe was nonseeing and contracted following a perforating injury. Secondary correction can now be planned

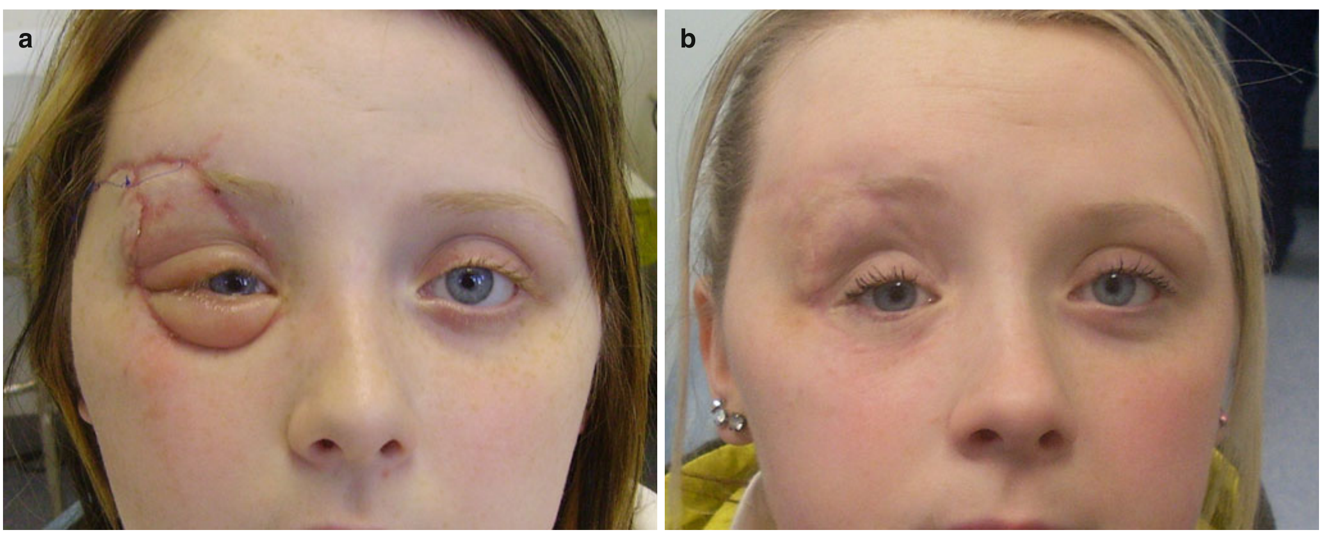

Fig. 19.13 Lymphoedema can persist for many months and need regular massage. (**a**, **b**) This high-energy injury resulted in loss of sight, extensive soft tissue injuries and comminution of the zygomatic complex (see also Fig. 8.25). The position of the lacerations significantly impeded lymphatic drainage

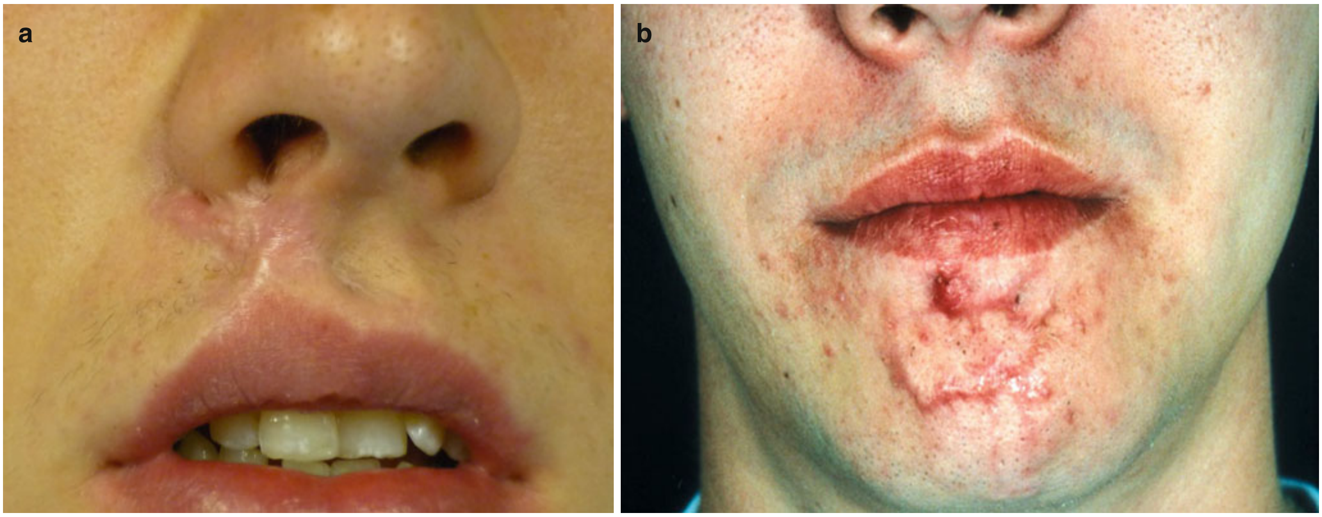

Fig. 19.14 Scar contraction and hypertrophy (**a**, **b**) need close monitoring and a highly compliant patient

Fig. 19.15 Early ectropion of the lower eyelid due to scar contraction. This needs vigorous massage and careful follow-up. Secondary correction can be very difficult and is often disappointing

Fig. 19.16 Early scar contraction following full-thickness laceration to the cheek (and associated fractures) (see also Fig. 8.144). A thick "band" of tissue can be palpated, with surrounding induration and limitation of mouth opening

Fig. 19.17 In addition to regular massage, the patient was supplied with an acrylic "gob-stopper" and upper appliance, thickened buccally (**a**, **b**). These were essentially devices to apply regular "inside-out" massage to the wound (**c**)

Fig. 19.18 Appearances at 9 months (**a**) and 1 year (**b**). The scar is now soft and compliant. Patient can easily displace the cheek with her tongue. Fat grafting has since been performed

19.1.9 Length and Frequency of Follow-up

This varies considerably and is influenced by many factors. While early discharge may "free up" time to see more patients, it is only with long-term follow-up that long-term outcomes can be known. However, what is meant by "long term"? Some complications (for instance condylar resorption, or mucocele formation) may take years to occur and some injuries (notably scars and nerve injuries) years to mature or recover. Conversely, untreated infections can rapidly progress over a matter of days in high-risk patients and may need very close follow-up initially.

Fig. 19.19 Discolouration of upper left central incisor following trauma 2 years ago

Follow up, whether it be weekly, monthly or annually is generally not based on biology, but rather on the Gregorian (the "Western" or "Christian") calendar. Annual review, for example, is based on the time it takes the earth to orbit the sun and not on any sound biological principles! For those cases needing more frequent review (such as infections or fractures managed nonsurgically) a pragmatic biological approach is ideally required on a case-by-case basis. In reality, this can prove to be very difficult in any busy clinical practice. Prolonged dental follow-up (usually by the patient's dentist) is often recommended. Teeth can devitalise and stain, even in the absence of obvious injury, either as a result of the initial impact or subsequent screw placement during fracture repair.

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